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Cretaceous Corbulid Bivalves of the Pacific Slope of North America

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Abstract. This paper presents the first biostratigraphic study of Cretaceous corbulid bivalves from shallow-marine rocks along the Pacific slope of North America, with most of the outcrops in California and northwestern Baja California. Five genera, two of which are new, and 14 species, 11 of which are new, are represented: *Caryocorbula* ***coani***, sp. nov., *Caryocorbula* ***onoensis***, sp. nov., *Caryocorbula* ***vacca***, sp. nov., *Caryocorbula traskii* (Gabb, 1864), *Caryocorbula* ***lomana***, sp. nov., ***Excorbula coqua***, gen. et. sp. nov., ***Excorbula parkyi***, gen. et sp. nov., ***Excorbula shastana***, gen. et sp. nov., ***Panzacorbula*** *pozo* (Dailey & Popenoe, 1966), gen. nov., *Eoursivivas cultriformis* (Gabb, 1864), *Caestocorbula* ***cavus***, sp. nov., *Caestocorbula* ***attina***, sp. nov., *Caestocorbula* ***aura***, sp. nov., and *Caestocorbula*? ***allisoni***, sp. nov. The cumulative chronologic range of these 14 corbulid species is Early Cretaceous (latest Aptian) to Late Cretaceous (early late Maastrichtian), an interval of 40 m.y. Generic diversity of the study area corbulids is greatest during the Turonian and late Campanian to early late Maastrichtian.

Caryocorbula Gardner, 1926, and *Caestocorbula* Vincent, 1910, have been only provisionally reported before from Cretaceous rocks in the study area. *Eoursivivas cultriformis*, of late early to early late Maastrichtian age, is the youngest record of this genus and its first occurrence in the Western Hemisphere. *Eoursivivas* was previously known only from Lower Cretaceous (Valangian to Hauterivian) strata of Japan. ***Excorbula*** and ***Panzacorbula*** are apparently endemic to the study area.

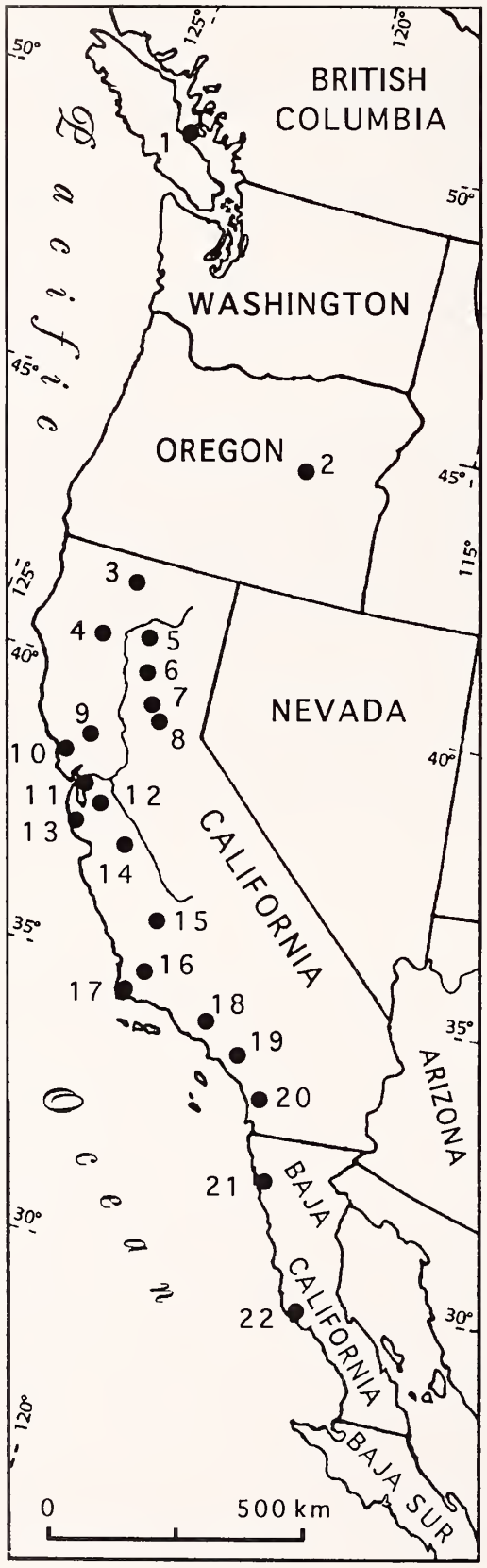
Caryocorbula ***onoensis***, of late early Albian age, is the earliest study area species to show evidence of predatory drilling.

INTRODUCTION

The earliest records of corbulids are of Middle Jurassic age from England (e.g., Morris & Lycett, 1854; Lycett, 1863; Cox & Arkell, 1948–1950; Duff, 1978; Harper et al., 2002); Africa (Cox, 1965); China (Yin & Fürsich, 1991; Yin & Fürsich, 1992); western India (Kanjilal, 1997; Singh & Rai, 1980; Fürsich et al., 2000); southern Mexico (Alencaster, 1963); Montana (Imlay, 1945, 1967), and Alberta, Canada (McLearn, 1924; Frebold, 1964). The majority of corbulid genera evolved during the Cretaceous and Eocene; the remainder radiated during the Miocene to Recent times (Lewy & Samtleben, 1979). Today, there are approximately 85 species (Coan et al., 2000), with most living in tropical and temperate waters of normal-marine salinities. Corbulids are sluggish burrowers, and most species live in nearshore, fine-grained sediments deposited in relatively low-energy environments. Some species range into the northern cold regions, and some species are euryhaline and live in normal marine to brackish waters. Some fossil corbulids are known to comprise monotypic shell beds associated with brackish-water conditions (Lewy & Samthleben, 1979).

Corbulids are widely distributed in Cretaceous shallow-marine faunas of the Pacific slope in British Columbia, Oregon, California, and northwestern Baja California, yet these small-sized fossils, which can be locally common, have been largely ignored by previous workers. Early paleontologists were mainly focused on ammonites, and studies of bivalves, as well as those of gastropods, were of secondary interest. If bivalves were investigated, then those consisting of large-sized specimens were favored. In recent years, we have been studying the fossil records of the more poorly known Cretaceous bivalves and gastropods from the region extending from Vancouver Island, British Columbia southward to Baja California, Mexico, in order to bring their biostratigraphic utility into the mainstream of geologic usage. This paper, which is one of these studies, is the first to record the stratigraphic succession of Cretaceous corbulids from the Pacific slope of North America.

The only other stratigraphic succession study on corbulids was done by Anderson (1996), who studied Neogene *Corbula* Bruguière, 1797, from the northern Dominican Republic. Coan (2002) studied the Recent eastern Pacific species of family Corbulidae Lamarck, 1818.



This present study stems from a careful search for corbulid specimens in all the major museums that have extensive collections of Cretaceous fossils from the study area. We detected 113 lots (72 = LACMIP, 21 = CAS, 15 = UCMP, 5 = other) containing a total of 1547 specimens. We were able to recognize five genera and 14 species; two of the genera and 11 of the species are new. We also refined the paleontologic record of the three previously named species. Pacific slope of North America corbulids have a cumulative geologic range of late early Albian to early late Maastrichtian, a span of approximately 40 million years. The locales and stage occurrences of the studied species are shown on Figures 1 and 2, respectively.

This present report establishes the first record for *Eoursivivas* Ota, 1964, in the Western Hemisphere and its youngest species. In addition, this report is the first to document the Cretaceous occurrence of *Caryocorbula* Gardner, 1926, and *Caestocorbula* Vincent, 1910, in the study area. Allison (1974) had used the last two names in various faunal lists pertaining to the upper Aptian Alisitos Formation in Baja California, Mexico, but he did not photographically document his identifications, nor did he assign any museum-catalog numbers to his specimens. We used the specimens that he collected, but his identifications were inconsistent.

Predatory Drill Holes in Corbulid Shells

Late Cretaceous, Cenozoic, and modern corbulid shells are commonly bored by gastropods (Taylor et al., 1983; Kelley & Hansen, 1993), and the drill holes are usually assigned to naticids or muricids, although a few other types of gastropods are also capabable of making these holes (see Harper et al., 1998). Kase & Ishikawa (2003) reported the chronologic range of naticids to be Late Cretaceous (Campanian) to Recent and that earlier reports of Late Triassic to Early Cretaceous naticid boreholes are invalid. Furthermore, they reported that naticid drill holes became common only in Campanian and Maastrichtian shallow-marine environments. Sohl (1969) reported the chronologic range of muricids to be Early Cretaceous to Recent and that their boring activity is well represented only from the Late Cretaceous (Senonian) onward. There are predatory drill holes in late Albian corbulids and other bivalves of England (Taylor et al., 1983). In addition, in

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Figure 1. Index map showing locales mentioned in the text. 1 = Hornby Island. 2 = Dayville area. 3 = Yreka. 4 = Ono and Texas Springs. 5 = East of Redding. 6 = Tuscan Springs. 7 = Chico Creek. 8 = Pentz. 9 = Sites. 10 = Gualala. 11 = Martinez. 12 = Corral Hollow. 13 = Pigeon Point. 14 = Ortigalita Creek. 15 = Reef Ridge. 16 = Pozo. 17 = Jalama Creek. 18 = Simi Hills. 19 = Santa Ana Mountains. 20 = Carlsbad. 21 = Punta China. 22 = Arroyo Santa Catarina.

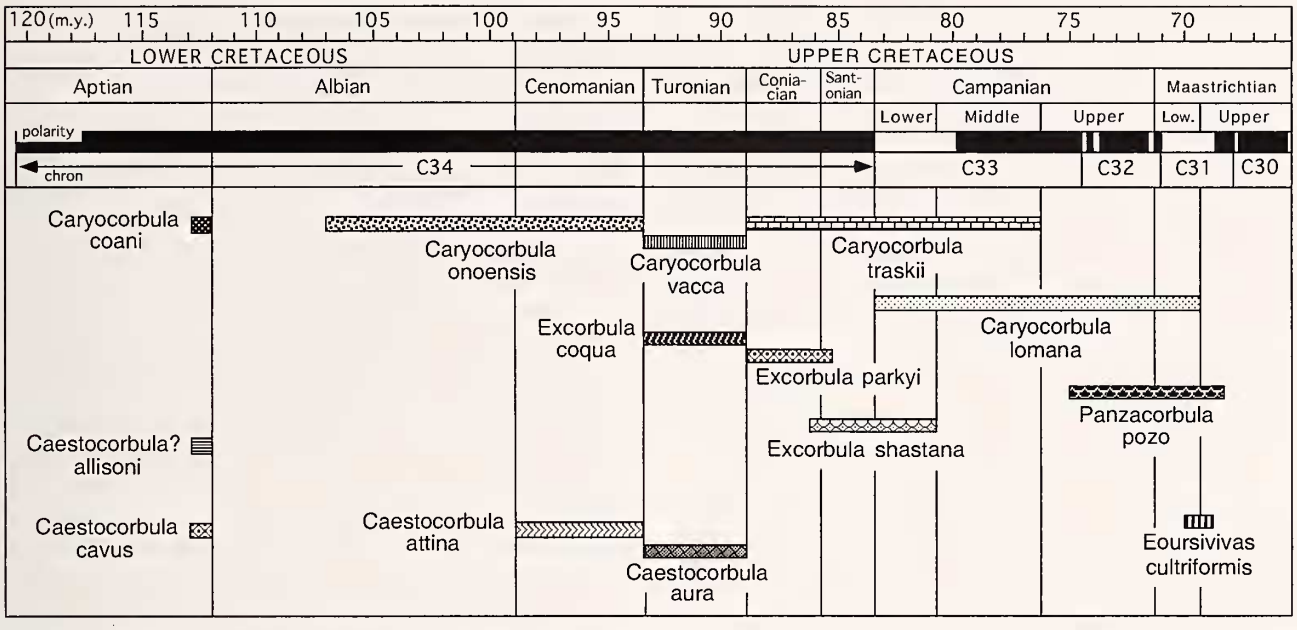

Figure 2. Chronostratigraphic positions of the new and restudied Cretaceous corbulids. Geologic ages, polarities, and chrons from Gradstein et al. (1994).

this present study, drill holes were found in a few valves of the late early Albian *Caryocorbula* ***onoensis***, sp. nov. This is the earliest corbulid species in the study area to show any evidence of drilling. Except for the late Aptian species and the Cenomanian *Caestocorbula* ***attina***, sp. nov., all the other study area species show drill holes, but, for the most part, these holes are rare to uncommon. Locally, however, drill holes are common only in the late Campanian to early Maastrichtian *Caryocorbula* ***lomana***, sp. nov. Details of drill-hole evidence are discussed for each species in "Systematic Paleontology."

Corbulids have discrete conchiolin (organic) layers within the microstructure of their valves (De Cauwer, 1985), and such layers are relatively rare in other marine bivalves (Taylor et al., 1973). As reviewed by Anderson (1992), it has been commonly reported that the conchiolin layers in corbulid shells inhibit predation by drilling gastropods. Anderson (1992), however, reported that other factors (e.g., variable shell thickness) are likely more important than presence of conchiolin.

The suprafamilial classification system used here follows that of Keen (1969). Abbreviations used for catalog and locality numbers are: ANSP, Academy of Natural Sciences of Philadelphia; CAS, California Academy of Sciences, San Francisco; CIT, California Institute of Technology, Pasadena [collections now housed at LACMIP]; CGS, California Geological Survey [collections now housed mostly at UCMP and Academy of Natural Sciences, Philadelphia]; GSC, Geological Survey of Canada, Ottawa, Ontario; LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section; SDSNH, San Diego Society of Natural History, San Diego; UCLA, University of California, Los Angeles [collections now housed at LACMIP]; UCMP, University of California Museum of Paleontology (Berkeley); USGS, United States Geological Survey (Menlo Park, California) [collections now housed at UCMP].

STRATIGRAPHY

The geologic ages and depositional environments of most of the formations and members cited in this paper have been summarized in recent papers by Squires & Saul (2001, 2002, 2003a, b, c, in press). Stratigraphic information mentioned below concerns either those rock units not discussed in recent literature or additional pertinent biostratigraphic details. The following stratigraphic units are listed from oldest to youngest.

Cretaceous Rocks near Sites

The type locality of *Caryocorbula* ***onoensis***, sp. nov. is near Sites, west side of Sacramento Valley, Colusa County, northern California (Figure 1, locale 9). In this area, Brown & Rich (1961) reported that reworked megafossils of Albian age are found in submarine-slump blocks, depicted within unit 7 (Cenomanian age) on their geologic map. Fossils at LACMIP loc. 24285, the type locality of *C.* ***onoensis*** are from one of these submarine-slump blocks. A few additional specimens of the new species were found a few kilometers to the north of the type locality, in unit 7, at USGS locs. M-175, M-176, M-177, and M-178 in the Cenomanian Antelope Shale.

Panoche Formation at Reef Ridge

The type locality of *Caestocorbula* ***attina***, sp. nov. is in the Panoche Formation, Reef Ridge (Figure 1, locale 15), Kings County, central California. Campanian-age conglomerate beds at this locality, LACMIP 25526, contain reworked cobbles with shallow-marine mollusks, and the new species is one of these mollusks. Two reworked gastropods have been identified: ?*Natica allisoni* (Murphy & Rodda, 1960) of Cenomanian age (Popenoe et al., 1987) and *Latiala californicus* Saul, 1998, of ?late Albian/Cenomanian age (Saul, 1998).

Gas Point Member of Budden Canyon Formation

This member crops out in the Bald Hills area near Ono (Figure 1, locale 4), Shasta County, northern California. The ammonite *Mesopuzosia pacifica* Matsumoto, 1954 occurs in all parts of the member (Murphy et al., 1969) and is indicative of Turonian age (Matsumoto, 1959). *Caryocorbula* ***vacca,*** sp. nov. occurs in the fine-grained, lower part of the member.

Northumberland Formation, Northwest Side of Hornby Island

Whiteaves (1879) reported *Corbula traskii*? Gabb, 1864, and *Corbula minima* d'Orbigny, 1847, of Whiteaves, 1879, [considered herein to be synonymous with *C. traskii*] from "the northwest side of Hornby Island," off the east coast of Vancouver Island, British Columbia (Figure 1, locale 1). Unfortunately, Whiteaves' geographic information is inexact, but according to the geologic map of Katnick & Mustard (2001), the only rocks that crop out on the northwest side of Hornby Island belong to the mudstone of the Northumberland Formation of the Nanaimo Group. Pending on-going research (P. Ward, personal communication) on the age of the various formations of the Nanaimo Group, we believe it best to refer to the age of the Northumberland Formation as undifferentiated Campanian.

Anchor Bay Member of Gualala Formation

This formation, which crops out in southern Mendocino County, northern California (Figure 1, locale 10), is part of a sedimentary block that has been tectonically transported a considerable distance northward from its point of origin, which according to Elder et al. (1998), was probably as far south as southern California. The occurrence of ***Panzacorbula***, gen. nov. *pozo* (Dailey & Popenoe, 1966) at USGS loc. M8830 in the Anchor Bay Member of this formation, therefore, is geographically anomalous. Based on molluscan taxa, this member is late Campanian to early Maastrichtian age (Elder et al., 1998).

Unnamed Upper Cretaceous Formation, Pozo District

At its type locality LACMIP 23774, abundant specimens of ***Panzacorbula*** *pozo* (Dailey & Popenoe, 1966) make up an almost monotypic shell bed deposited under brackish-water-conditions in unnamed strata approximately 4 km northwest of the hamlet of Pozo (Figure 1, locale 16), east of Santa Margarita Lake, La Panza Range, west-central Coast Ranges, San Luis Obispo County, central California. The Upper Cretaceous rocks in this area have never been assigned to a formation. Dailey & Popenoe (1966:19) mentioned the type locality but did not assign an age to the rocks. Howell et al. (1977:fig. 12) provided a geologic map of the Pozo district and mapped the rocks in the immediate area of the locality (i.e., Toro Creek, section 7) as part of an unnamed Upper Cretaceous sandstone deposited in a shallow marine-canyon head. Vedder (1977:108) and Throckmorton (1988:220) provided faunal lists of mollusks found at this locality, and Vedder reported an age of late Campanian and/or early Maastrichtian for these mollusks.

Tesla Formation

This formation crops out as two sandstone members near Corral Hollow (Figure 1, locale 12) in the area between the cities of Livermore and Tracy in the eastern part of the central Diablo Range, western edge of the San Joaquin Valley, Alameda County, northern California. This formation ranges in age from Late Cretaceous into the middle Eocene, and possibly late Eocene. Specimens of ***Panzacorbula*** *pozo* are found near the base of the lower sandstone member, which was deposited in a brackish-water environment, and the reportedly early Maastrichtian molluscan assemblage in these rocks is very similar to that found at the above-mentioned type locality of this species in the Pozo district (Throckmorton, 1988).

PREVIOUS TAXA ASSIGNED TO *CORBULA* FROM THE STUDY AREA

Although previous workers loosely applied the name "*Corbula*" to nine "Cretaceous" species of the Pacific slope of North America, only four of these, *Corbula cultriformis* Gabb, 1864; *Corbula traskii* Gabb, 1864; *Corbula minima* d'Orbigny of Whiteaves, 1879 [considered herein to be synonymous with *C. traskii*]; and *Corbula pozo* Daily & Popenoe (1966) can be substantiated as being Cretaceous corbulids. They are discussed and illustrated in this paper. The other five species are discussed, in ascending stratigraphic order, in the following paragraphs.

Corbula concinna Whiteaves (1884:219, pl. 29, figs. 3, 3a) was originally reported from outcrops along the south side of Alliford Bay, Skidegate Inlet, Maude Island area in the Queen Charlotte Islands, British Columbia. These

outcrops are of the Yakoun Formation of Middle Jurassic (Bajocian) age (McLearn, 1949). *Corbula concinna* differs significantly from corbulids by having on both valves, especially the left valve, a very prominent and projecting beak and by having a trapedzoidal left valve. This species might be an astartid.

Corbula? *persulcata* Stanton (1895:61–62, pl. 11, fig. 3) was reported from limestone strata 5 km northwest of Paskenta, Tehama County, northern California. This limestone, which is part of the Stony Creek Formation of the Great Valley Series, is of latest Jurassic (Tithonian) age and contains in situ chemosynthetic mollusks that lived in a deep-marine setting dominated by turbidites (Campbell et al., 1993). It is not possible, with the available material, to positively assign Stanton's species to any family or genus because the species is known only from the holotype, and its dorsal posterior end is missing. *Corbula*? *persulcata,* however, differs from any known study area Cretaceous corbulid by having widely spaced commarginal furrows.

Corbula filosa Stanton (1895:62, pl. 11, figs. 1, 2) was originally reported from the Paskenta Group, Cold Fork of Cottonwood Creek, Tehama County, northern California. The age of these rocks is earliest Cretaceous (Berriasian) (Campbell et al., 1993). *Corbula filosa* does not appear to be a corbulid. Its projected to rounded anterior end, variable presence of an ill-defined posterior slope on the right valve, and an extremely broad posterior slope (when present) on the right valve suggest that it might be a venerid.

?*Corbula primorsa* Gabb (1864:148, pl. 22, figs. 120, 120a) was originally reported from probably Cretaceous rocks on the south side of Corral Hollow, just southeast of Tesla, Alameda County, north-central California, but the location information is inexact. Stewart (1930:7) reported that the type specimens of this species have been lost. Because it is not known what beds ?*Corbula primorsa* came from and because the types are lost, this species is deemed by us to be a *nomen dubiun.*

Corbula parilis Gabb (1864:150, pl. 29, figs. 239, 239a) was originally reported as questionably of Cretaceous age and from Martinez, northern California. Although this species belongs to *Caryocorbula,* it is an Eocene one that ranges from San Diego, southern California through southwestern Oregon, in rocks of early ("Capay Stage") through middle ("Transition Stage") Eocene age (Squires, 1987).

SYSTEMATIC PALEONTOLOGY

Phylum MOLLUSCA Linnaeus, 1758

Class BIVALVIA Linnaeus, 1758

Order MYOIDA Stoliczka, 1870

Family CORBULIDAE Lamarck, 1818

Diagnosis: Shell small to medium, inequilateral, inequivalved to sub-inequivalved, aragonitic, with crossed-lamellar outer and complex crossed-lamellar inner layers. Ligament partly external, internal portion amphidetic. Right valve generally strongly inflated and larger than left valve, to a varying degree. Posterior end somewhat rostrate. Shell sculptured with commarginal ribs or smooth; radial ribs usually absent. Hinge simple with pit in left valve and corresponding anterior cardinal tooth in right valve. Chondrophore of left valve usually present, usually small, and variable in amount of projection. Muscle scars dimyarian. Pallial sinus small or absent (Vokes, 1945; Keen, 1969; Davies, 1971; Anderson, 1996; Coan, 2002).

Discussion: Corbulids have traditionally been placed in order Myoida, but molecular, conchological, and anatomical evidence suggests that corbulids might be more appropriately aligned to veneroids. Anderson & Roopnarine (2003) have summarized this evidence.

Dall (1898, 1900), Vokes (1945), and Keen (1969) did detailed systematic studies on Corbulidae. These bivalves have been largely split and grouped on shape and sculpture. Dentition, especially the shape of the chondrophore, and other shell features have been utilized, to some extent, as well. As indicated by Coan et al. (2000) and Coan (2002), inspection of the literature readily shows that early attempts to subdivide this family into subfamilies, genera, and subgenera were not successful. To date, however, there have been no rigorous morphology-based phylogenetic analyses of all the named genera, but Anderson & Roopnarine (2003) have done a rigorous phylogenetic analysis of Neogene genera and subgenera of the Corbulidae from tropical America.

In this present study, we endeavored to incorporate all available morphologic characters when assigning the species to the various genera. The key characters of these genera, as well as the study area species assigned to them, are given in Table 1. The biggest problem in working with Cretaceous corbulids, especially those from the study area, is the difficultly in cleaning the hinges of the small species (i.e., length less than 15 mm). They are almost always encased in well cemented matrix, and cleaning of the delicate chondrophore is very risky and can easily result in irreversible damage to the shell. For these particular species, a more effective technique is to inspect weathered specimens for those that show the dorsal surface of the chondrophore. In many of these cases, only minimal cleaning is required. At least the presence of the chondrophore can be determined, as well as whether or not it is projecting.

Subfamily CORBULINAE Lamarck, 1818

Diagnosis: Right valve slightly larger than left valve, valves more or less irregular in shape, from strongly inequivalve to subequivalve, posterior end somewhat rostrate. Ligament fitting into pit on hinge of left valve or onto expanded, usually projecting chondrophore (Keen, 1969; Coan et al., 2000).

Table 1

Check list of key morphologic characters used in differentiating the new taxa.

Taxa	Size	Left-valve sculpture	Right-valve sculpture	Other
Caryocorbula: elongate-ovate, valves tapered posteriorly, sculpture similar on both valves, single radial keel.				
*C. **coani***	medium	nearly smooth	nearly smooth	posterior keel very low
*C. **ouoeusis***	small	weak to medium	weak to medium	—
*C. **vacca***	small	very weak to weak	very weak to weak	minute radial threads possible
*C. **traskii***	medium	nearly smooth	very weak	—
*C. **lomana***	very small	very weak to weak	very weak to weak	quadrate shell, posterior slope squarish
Excorbula: trigonal, left valve smooth or nearly smooth, right valve initially smooth or with very weak ribs becoming stronger ventrally, right valve with two narrowly spaced keels.				
E. coqua	small	very weak	strong	—
E. parkyi	medium	smooth	strong	posterior slope groove-like
E. shastana	small	smooth	medium	posterior slope moderately wide
Pauzacorbula: subpyriform, single keel obsolete on mature specimens.				
***P.** pozo*	medium	very weak to weak	strong	—
Eoursivivas: very elongate, subdued irregular bands on valves, keel weak.				
E. cultriformis	medium	weak	weak	—
Caestocorbula: left valve much smaller, less inflated, less rostrate, and with weaker ribs than right valve.				
*C. **cavus***	small	very weak	weak	—
*C. **attrina***	very small	very weak	very weak to weak	—
*C. **aura***	small	weak	weak	umbo of right valve smooth
*C.? **attisoni***	small	medium	weak to strong	both valves bulbous

Discussion: We agree with Coan (2002:50), who reported there are a "bewildering array of specific and generic taxa in this subfamily," but many of the species found in this present study readily can be shown to belong to *Caryocorbula.*

Genus *Caryocorbula* Gardner, 1926

Type species: *Corbula alabamiensis* Lea, 1833, by original designation; middle Eocene, southeastern United States.

Diagnosis: Shell small to moderate, subquadrate to elongate ovate, inequilateral, right valve slightly larger and deeper than left. Posterior slope acutely set off by radial keel. Valves usually pointed (tapered) posteriorly. Umbones not inflated, nor set off by growth stages; beaks slightly prosogyrate. Lunule and escutcheon absent. Sculpture of weak to moderately strong commarginal ribs, similar on both valves; radial threads possibly present. Left-valve hinge with chondrophore and (posteriorly) adjoining deep pit. Chondrophore moderately broad, somewhat projecting and flattish, and bearing median ridge. Right-valve hinge with single, large triangular cardinal tooth (upcurved at tip) and adjoining deep, broad

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Figures 3–20. Specimens coated with ammonium chloride. Figures 3–6. *Caryocorbula **coani*** Squires & Saul, sp. nov., UCMP loc. A-6273. Figure 3. Paratype UCMP 155536, left valve, ×2.2. Figure 4. Paratype UCMP 155537, left valve, ×2.8. Figures 5, 6. Holotype UCMP 155535, ×2.3. Figure 5. Right view. Figure 6. Dorsal view. Figures 7–9. *Caryocorbula **ououeusis*** Squires & Saul, sp. nov. Figure 7. Holotype LACMIP 13100, LACMIP loc. 24285, left valve, ×3.8. Figure 8. Paratype LACMIP 13101, loc. 29230, right valve, ×4.5. Figure 9. Paratype LACMIP 13102, LACMIP loc. 24285, right valve, showing predatory drill hole, ×3.3. Figures 10–12. *Caryocorbula **vacca*** Squires & Saul, sp. nov. Figure 10. Holotype LACMIP 13103, LACMIP loc. 24365, left valve, ×5. Figure 11. Paratype LACMIP 13104, LACMIP loc. 10764, right valve, ×4.5. Figure 12. Holotype LACMIP 13103, LACMIP loc. 24365, dorsal view, ×5.2. Figures 13–17. *Caryocorbula traskii* (Gabb, 1864). Figure 13. Lectotype UCMP 155538, CGS loc. 145, left valve, ×5.5. Figure 14. Hypotype LACMIP 13105, LACMIP loc. 22406, left valve, ×3.7. Figure 15. Hypotype GSC 5742, NW side Hornby Island, British Columbia, left valve, ×7.5. Figure 16. Hypotype LACMIP 13106, LACMIP loc. 22406, right valve, ×3.9. Figure 17. Hypotype LACMIP 13107, LACMIP loc. 10832, dorsal view, ×8. Figures 18–20. *Caryocorbula **lomana*** Squires & Saul, sp. nov. Figure 18. Holotype SDSNH 81140, SDSNH loc. 3387, left valve, ×11.5. Figure 19. Paratype SDSNH 81141, SDSNH loc. 3162-C, left valve, ×8.4. Figure 20. Paratype LACMIP 13108, LACMIP loc. 7792, right valve, ×8.2.


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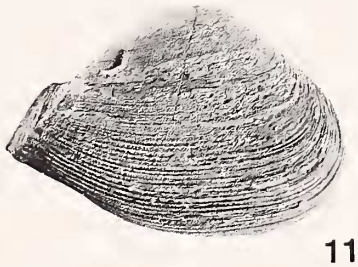
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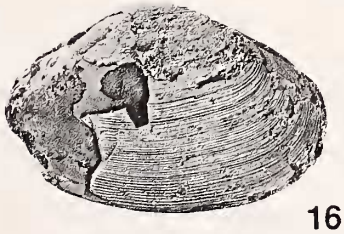
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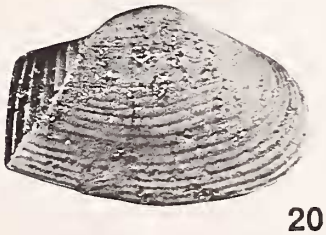
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pit. Adductor scars prominent. Pallial sinus simple, short, nearly vertical, and shallow to absent (Vokes, 1945; Stenzel et al., 1957; Keen, 1969; Coan et al., 2000; Coan, 2002).

Discussion: Coan (2002) gave taxonomic details concerning *Caryocorbula,* whereas Vokes (1945) and Stenzel et al. (1957) gave detailed descriptions of the type species of *Caryocorbula.* Stenzel et al. (1957) also provided a very useful, labelled drawing of the hinge features of the type species.

Some workers (e.g., Keen, 1969; Anderson, 1996; Coan, 2002) included *Caryocorbula* as a subgenus of genus *Corbula* Bruguière, 1797. Other workers (e.g., Vokes, 1945; Stenzel et al., 1957; Mikkelsen & Bieler, 2001), however, treated *Caryocorbula* as a distinct genus. It is important to emphasize that *Caryocorbula* differs from *Corbula* sensu stricto (type species *Corbula sulcata* Lamarck, 1801) by having a projecting chondrophore on the left-valve hinge and an absence of a small posterior tooth behind the pit on the right-valve hinge. *Corbula,* furthermore, is also unlike most other corbulines in not have a projecting chondropore on the left-valve hinge. We believe, therefore, that *Caryocorbula* should not be a subgenus of *Corbula.*

The chronologic range of *Caryocorbula* is Middle Jurassic to Recent. Its earliest record is apparently *Corbula tanganyicensis* Cox (1965) from Middle Jurassic (Bajocian?) of Tanganyika, east Africa. *Corbula attenuata* Lycett (1863) from the slightly younger Middle Jurassic (Bathonian) Great Oolite beds of England appears to be the second earliest species of *Caryocorbula.* We believe that both of these species have the main characters of *Caryocorbula.*

Caryocorbula ***coani*** Squires & Saul, sp. nov.

(Figures 3–6)

Diagnosis: Medium *Caryocorbula* with shell subquadrate. Commarginal ribs on both valves weak, poorly developed; valves overall smoothish. Posterior keel very low.

Description: Shell medium (maximum length 21.4 mm), longer than high. Valves subquadrate to somewhat ovate-elongate, moderately inflated, and nearly equivalved. Left valve very slightly smaller than right valve and subequilateral. Anterior end rounded. Posterior end variable in amount of elongation, ranging from slight to moderate. Posterior keel very low. Umbones low, anterior to midline of valves; beaks just anterior to midline. Lunule and escutcheon absent. Sculpture on both valves consisting of closely spaced, weak strength commarginal ribs, best developed near ventral margin and anteriorly becoming less tangential to ventral margin. Right-valve hinge with single, large cardinal tooth; adjoining pit deep.

Dimensions of holotype: Conjoined valves, height 13 mm, length 19.9, thickness 8.6 mm.

Holotype: UCMP 155535.

Type locality: UCMP loc. A-6273, 31°31′N, 116°41′W.

Paratypes: UCMP 155536 and 155537.

Geologic age: Late Aptian.

Distribution: Alisitos Formation, upper member, near Punta China, northwestern Baja California, Mexico (Figure 1, locale 21).

Discussion: This new species is based on nine specimens: eight pairs of conjoined valves and one right valve. All are from the same locality. Most are badly weathered and/or somewhat crushed. Sculpture is either worn, weathered, or poorly developed, except near the ventral margins, thereby imparting an apparent smoothness to the valves. One of the specimens borrowed from the UCMP collection had been cut in half, parallel to the hinge, thereby revealing the presence of this tooth. No predatory drill holes were found on any of the specimens.

Only a few of the specimens (e.g., Figure 3) of the new species have the posteriorly tapered valves that are normally characteristic of *Caryocorbula.* The new species, nevertheless, is placed in *Caryocorbula* on the basis of similarity in size, inflatedness, and sculpture of both of the valves, as well as an absence of a lunule or escutcheon.

The new species is most similar to *Caryocorbula betsyae* Marincovich (1993:23, 26, figs. 13.1–13.20, 14.1–14.6), from lower Cenozoic (Danian) strata in northern Alaska. Like the new species, the posterior elongation of *C. betsyae* ranges from slight to moderate (e.g., see Marincovich, 1993, figs. 13.3 and 13.6). In addition, *C. betsyae* has very weak sculpture, like that found on the new species. *Caryocorbula* ***coani*** differs from *C. betsyae* by having a weaker keel and sculpture that is not irregularly rugose.

Etymology: The species is named for Eugene V. Coan, in recognition of his many valuable contributions to the study of bivalves.

Caryocorbula ***onoensis*** Squires & Saul, sp. nov.

(Figures 7–9)

Diagnosis: Small *Caryocorbula.* Commarginal ribs on both valves moderately closely spaced, weak to medium, becoming stronger ventrally. Posterior keel moderately low.

Description: Shell small (maximum length 11.6 mm), longer than high. Valves trigonal ovate, tapered posteriorly, moderately inflated, and subequilateral. Anterior end rounded. Posterior end subtruncate. Posterior slope on both valves subvertical, with growth lines only, and set

off by moderately low, straight keel. Umbones moderately high, at midline of valves; beaks prosogyrate, just anterior to midline. Lunule and escutcheon absent. Sculpture on both valves consisting of moderately closely spaced, weak to medium strength commarginal ribs, and overlapping shinglelike. Sculpture on each valve, strongest ventrally, especially on left valve. Ribs on left valve also becoming more widely spaced ventrally and showing prominent growth lines. Right-valve umbo can be smooth (worn?). Left-valve hinge with projecting chondrophore; adjoining pit deep.

Dimensions of holotype: Left valve, 7.9 mm in height, 11.4 mm in length.

Holotype: LACMIP 13100.

Type locality: LACMIP loc. 24285, 39°16′40″N, 122°19′52″W.

Paratypes: LACMIP 13101 and 13102.

Geologic age: Late early Albian to Cenomanian.

Distribution: UPPER LOWER ALBIAN: Budden Canyon Formation, Chickabally Member, Texas Springs, Shasta County, northern California (Figure 1, locale 4). CENOMANIAN: Great Valley Series, in lower part of informal Antelope Shale at "Peterson Ranch," north of Sites, Colusa County, northern California (type locality) (Figure 1, locale 9). UPPER ALBIAN TO UNDIFFERENTIATED CENOMANIAN: Budden Canyon Formation, Bald Hills Member, Bald Hills near Ono, Shasta County, northern California (Figure 1, locale 4).

Discussion: This new species is based on 38 specimens: 25 right vales and 13 left valves. No conjoined valves were found. Specimen are most abundant at LACMIP loc. 29230, located at Texas Springs, near Ono, northern California. The holotype and paratype are somewhat worn, but they are most complete specimens available. Only a single specimen (Figure 9) shows a predatory drill hole.

The new species is similar to *Corbula tanganyicensis* Cox (1965:122, pl. 19, figs. 9a, 9b, 12a–d) from Middle Jurassic (Bajocian?) of Tanganyika, East Africa. The new species differs by being larger and having a more elongate right valve. The new species is also similar to *Corbula attenuata* Lycett (1863:62–63, pl. 37, figs. 6, 6a) from the Middle Jurassic (Bathonian) Great Oolite of England, but the new species differs by having slightly stronger sculpture and a less pronounced keel on the left valve.

The new species resembles *Corbula lineata* Müller (1847:26, pl. 2, figs. 6; Holzapfel, 1889:146–147, pl. 10, figs, 16–19) from the Greensand beds of Vaals and Aachen, Germany, which are of earliest Campanian age (Albers, 1976). We believe that Müller's species has all the characteristics of a *Caryocorbula*. The new species differs from *Caryocorbula lineata* by having fewer commarginal ribs with deeper interspaces, and a somewhat more rostrate right valve.

Etymology: The new species is named for Ono, California.

Caryocorbula ***vacca*** Squires & Saul, sp. nov.

(Figures 10–12)

Diagnosis: Small *Caryocorbula*. Commarginal ribs on both valves very closely spaced and very weak (mainly) to weak strength, occasionally crossed by minute radial threads, posterior keel low to moderately strong. Posterior end with short rostrum.

Description: Shell small (maximum length 9.6 mm), longer than high. Valves trigonal ovate, tapered posteriorly, moderately inflated, and subequilateral. Left valve slightly smaller than right valve. Anterior end rounded. Posterior end projected into short rostrum. Posterior slope wide, flattish, at moderate angle and set off by low to moderately strong, straight keel; rostrum short, truncate. Umbones moderately high, at midline of valves; beaks prosogyrate, just anterior to midline. Sculpture similar on both valves and consisting of closely spaced (6 to 10 ribs/mm) very weak (mainly) to weak strength commarginal ribs; occasionally intersected, on both valves, by minute radial threads (especially on umbones). Commarginal ribs continue onto posterior slope. On some specimens, ventral parts of both valves curl hingeward with growth, causing change in slope of disk; ribs on curled part becoming slightly stronger, wavy, and with deep interspaces. Left-valve hinge with slightly projecting chondrophore; adjoining pit wide and deep. Right-valve hinge with single, large cardinal tooth; adjoining pit deep. Pallial line simple, well developed, not indented.

Dimensions of holotype: Conjoined valves, 6 mm in height, 9.5 mm in length, 4.5 mm in thickness.

Holotype: LACMIP 13103.

Type locality: LACMIP loc. 24365, 40°39′10″N, 122°6′25″W.

Paratype: LACMIP 13104.

Geologic age: Turonian.

Distribution: Hornbrook Formation, Osburger Gulch Member, Yreka area, Siskiyou County, northern California (Figure 1, locale 3); Redding Formation, Bellavista Sandstone and Frazier Siltstone (type locality) members, east of Redding, Shasta County, northern California (Figure 1, locale 5); Budden Canyon Formation, lower part of Gas Point Member, near Ono, Shasta County, northern California (Figure 1, locale 4); Ladd Formation, Baker Canyon Member, Santa Ana Mountains, Orange County, southern California (Figure 1, locale 19).

Discussion: This new species is based on 98 specimens:

57 right valves, 34 left valves, and seven pairs of conjoined-valves. Only one valve (right valve) has a predatory drill hole. At LACMIP loc. 10079 in the Baker Canyon Member, the new species co-occurs with ***Excorbula coqua***, gen. et sp. nov.

The new species is similar to *Corbula truncata* Sowerby (1836:240, 341, pl. 16, fig. 8; Woods, 1908:215, pl. 34, figs. 17–22) from the upper Albian Upper Greensand in England but differs from *C. truncata* by having radial riblets, slightly stronger commarginal ribs, and on the left valve, a weaker rostrum. We believe that Sowerby's species belongs to *Caryocorbula*.

Caryocorbula ***vacca*** is intermediate in morphology between *C.* ***ouoeusis*** and *C. traskii*. *Caryocorbula* ***vacca*** differs from *C.* ***ouoeusis*** by having weaker and more closely spaced ribs, and *C.* ***vacca*** differs from *C. traskii* by having much more prominent ribs on the left valve and stronger and more widely spaced ribs on the right valve.

Etymology: The species is named for its occurrence in Little Cow Creek Valley, east of Redding, Shasta County; Latin, *vacca* meaning cow.

Caryocorbula traskii (Gabb, 1864)

(Figures 13–17)

Corbula traskii Gabb, 1864:149, pl. 22, figs. 121, 121a.

Corbula minima d'Orbigny. Whiteaves, 1879:138, pl. 17, figs. 4, 4a.

Corbula traskii? Gabb. Whiteaves, 1879:138, pl. 17, fig. 3.

Diagnosis: Medium *Caryocorbula* with left valve nearly smooth. Commarginal ribs on right valve very closely spaced and very weak. Posterior keel very low on both valves.

Description: Shell medium (maximum length 15 mm), longer than high. Valves trigonal ovate, tapered posteriorly, moderately inflated, subequilateral, and nearly equivalved. Left valve very slightly smaller and slightly less inflated than right valve. Anterior end rounded. Posterior end somewhat truncate. Posterior keel very low on both valves. Umbones moderately low, at midline of valves; beaks prosogyrate, just anterior to midline. Lunule and escutcheon absent. Left valve with very weak commarginal ribs to nearly smooth. Right valve with very closely spaced (approximately 11 ribs/mm on adult), very weak strength commarginal ribs; rarely becoming somewhat wavy ventrally. Left-valve hinge with projecting chondrophore separated into two parts by shallow groove, widening posteriorly.

Dimensions of lectotype: Left valve, 5.3 mm in height, 8.3 mm in length.

Lectotype: UCMP 155538 [= CGS 145], designated here.

Type locality: Exact location unknown, Pentz, Butte County, northern California.

Geologic age: Coniacian to middle Campanian.

Distribution: CONIACIAN: Chico Formation, Ponderosa Way Member, Chico Creek, Butte County, northern California (Figure 1, locale 7). SANTONIAN: Redding Formation, Member V, east of Redding, Shasta County, northern California (Figure 1, locale 5); Chico Formation, Musty Buck Member, Chico Creek, Butte County, northern California (Figure 1, locale 7). LOWER CAMPANIAN: Chico Formation, Ten Mile Member, Chico Creek, Butte County, northern California (Figure 1, locale 7); Chico Formation, Pentz Road member (informal), Butte County, northern California (type locality) (Figure 1, locale 8); Chico Formation, ?Tuscan Springs, Tehama County, northern California (Figure 1, locale 6); Ladd Formation, Holz Shale Member (upper part), Santa Ana Mountains, Orange County, southern California (Figure 1, locale 19); Williams Formation, Schulz Member, Santa Ana Mountains, Orange County, southern California (Figure 1, locale 19). MIDDLE CAMPANIAN: Pigeon Point Formation, south of San Francisco, San Mateo County, northern California (Figure 1, locale 13); Chatsworth Formation, Bell and Dayton canyons, Simi Hills, Ventura County, southern California (Figure 1, locale 18). UNDIFFERENTIATED CAMPANIAN: Northumberland Formation, northwest side of Hornby Island, east side of Vancouver Island, British Columbia (Figure 1, locale 1).

Discussion: This study of Gabb's species is based on 511 specimens (including Gabb's original material): 295 right valves, 127 left valves, and 89 pairs of conjoined valves. Five specimens (all right valves) show predatory drill holes.

Corbula traskii Gabb (1864:149, pl. 22, figs. 121, 121a) was originally reported from Texas Flat, Placer County; Tuscan Springs, Tehama County; and Pentz [= Pence's Ranch], Butte County, northern California. According to Stewart (1930:289), UCMP has a number of specimens which are presumably the original material upon which Gabb based his species. Our search of the UCMP collection resulted in the discovery of two cabinets containing original material formerly stored under the auspices of the old California Geological Survey collection. A box labelled "CGS no. 145, original material," contains several specimens of *Corbula* and possibly several other genera of bivalves. Because Gabb did not designate a holotype, we selected the best preserved specimen (Figure 14) to serve as the lectotype. It has labels glued to it that identify the specimen as *Corbula traskii* Gabb and as CGS 145. This specimen is indistinguishable in morphology from the other specimens of this species from Pentz.

A poorly preserved specimen questionably labelled as from Tuscan Springs is also among the original material

of Gabb's stored at UCMP. No original material was found from Texas Flat, thus this occurrence could not be verified.

Whiteaves (1879:138, pl. 17, fig. 3.) reported *C. traskii*? from the northwest side of Hornby Island, but, according to him, the specimens are too poorly preserved for positive specific identification. His illustrated specimen appears to be an internal mold. There are no GSC numbers for any of these specimens mentioned by Whiteaves, and they were not found by Bolton (1965).

Whiteaves (1879:138, pl. 17, figs. 4, 4a) also reported *Corbula minima* d'Orbigny, 1847, from the northwest side of Hornby Island, east side of Vancouver Island, British Columbia. Whiteaves (1879) illustrated a left and a right valve, but only the left valve (GSC hypotype 5742) was detected by Bolton (1965:99). Examination of the left-valve specimen (GSC hypotype 5742) revealed that it is *Caryocorbula traskii,* and an illustration (Figure 15) is provided here.

Caryocorbula traskii is similar to *Corbula broggii* Olsson (1944:65–66, pl. 6, figs. I–3) from Maastrichtian strata in the Paita region of northern Peru, and even Olsson remarked on the similarity. *Caryocorbula traskii* differs from the Peruvian species by having more inflated valves and finer ribs.

Caryocorbula ***lomana*** Squires & Saul, sp. nov.

(Figures 18–22)

Diagnosis: Very small *Caryocorbula* with shell usually quadrate. Commarginal ribs on both valves very weak to weak. Posterior slope usually squarish, bearing ribs more widely spaced and more prominent than elsewhere.

Description: Shell very small (maximum length 6 mm), longer than high. Valves usually quadrate, rarely trigonal, lowly inflated, and inequilateral. Left valve slightly smaller than right valve. Anterior end rounded. Posterior end truncate. Posterior dorsal margin of right valve ridged and parallel or subparallel to hinge. Posterior keel sharp on both valves. Posterior slope wide and tall. Umbones low, at midline of valves; beaks prosogyrate, just anterior to midline. Lunule and escutcheon absent. Sculpture on both valves usually consisting of very weak to weak, closely spaced commarginal ribs; some variability in rib strength, ranging from moderately weak to moderately strong. Posterior slope on both valves with fewer ribs, but more widely spaced and usually more prominent than elsewhere. Left valve with microscopic radials in interspaces between ribs and minute, raised radial threads on anterior or posterior part of valve. Left-valve hinge with projecting chondrophore, flattish with median groove; adjoining pit narrow and deep. Right-valve hinge with small cardinal tooth; adjoining pit wide and deep. Right-valve interior grooved for reception of margin of left valve. Posterior ends of both valves flattened and somewhat projected, with extreme postero-ventral margin bluntly pointed where keel meets ventral margin. Pallial line simple, nearly vertical posteriorly, with slight indentation. Adductor muscle scars prominent, posterior one larger.

Dimensions of holotype: Conjoined valves, 3 mm in height, 4.6 mm in length, 2 mm in thickness.

Holotype: SDSNH 81140.

Type locality: SDSNH loc. 3387, 33°8′22N, 117°17′0″W.

Paratypes: SDSNH 81141 and 81142; LACMIP 13108 and 13109.

Geologic age: Campanian to early Maastrichtian.

Distribution: LOWER CAMPANIAN: Chico Formation, Ten Mile Member, Chico Creek, Butte County, northern California (Figure 1, locale 7). MIDDLE CAMPANIAN: Chatsworth Formation, Simi Hills, Ventura County, southern California (Figure 1, locale 18). UPPER CAMPANIAN TO LOWER MAASTRICHTIAN: Point Loma Formation, Carlsbad area, San Diego County, southern California (type locality) (Figure 1, locale 20); Rosario Formation, Arroyo Santa Catarina, northwestern Baja California, Mexico (Figure 1, locale 22).

Discussion: This new species is based on 289 specimens: 119 right valves, 60 left valves, and 110 pairs of conjoined valves. Preservation is excellent for specimens from the Point Loma Formation, and specimens were particularly abundant from that stratigraphic unit at SDSNH loc. 3387. This locality yielded 239 specimens: 85 left valves, 51 right valves, and 103 pairs of conjoined valves. Thirty-six of these 239 specimens show predatory drill holes: 14 on left valves and 19 on right valves.

The new species resembles *Corbula swedesboroensis* Weller (1907:644–645, pl. 72, figs. 33–36) from Campanian strata of New Jersey but differs from Weller's species by having a more quadrate rostrum with stronger and more widely spaced commarginal ribs. The left valve of Weller's species is not known.

The usually squarish rostrum on the new species resembles that found on *Tenuicorbula tenuis* (Sowerby, 1833:36; Olsson, 1961:434, pl. 77, figs. 3, 3a), the type species of the Miocene to Recent *Tenuicorbula* Olsson, 1932, known from Central and South America. The new species differs from *T. tenuis* by having smaller size, much less elongate shell, ribs more widely spaced on rostrum, only a single rather than a double keel on both valves, and a straighter keel.

Etymology: The species is named for the Point Loma Formation, San Diego County, southern California.

Genus ***Excorbula*** Squires & Saul, gen. nov.

Type species: ***Excorbula parkyi***, sp. nov.; Late Cretaceous (Turonian to Santonian), California.

Diagnosis: Shell small to medium, trigonal to trigonal-oblong, with subequilateral, equally inflated, and nearly equal-sized valves. Left valve smooth or with very weak commarginal ribs, rarely with weakly ribbed nepionic cap. Right valve initially smooth or with very weak ribs becoming stronger toward venter. Posterior slope on right valve very narrow (groovelike) to moderately wide, and set off by two, narrowly spaced keels close to valve margin; one keel emanating from approximately midline of valve and other keel formed by ridge along posterior dorsal margin. Left-valve hinge with inclined, slightly projecting spoon-shaped chondrophore bearing median groove. Right-valve hinge with large, single cardinal tooth; adjoining pit deep.

Discussion: The new genus resembles *Ursirivus* Vokes, 1945, a Cenomanian corbulid, but the new genus has a more trigonal shape, discrepant sculpture, and an absence of a deep lunule.

The new genus also resembles *Vokesula* Stenzel & Twining in Stenzel et al., 1957, which ranges from the early Eocene to early Oligocene (Stenzel et al., 1957; Keen, 1969), but the new genus has less discrepant-sized valves, and two keels rather than only one on the right valve. In addition, ***Excorbula*** has a less inflated and proportionally shorter right valve with narrower umbones than *Vokesula.*

The new genus resembles *Varicorbula* Grant & Gale, 1931, which ranges from the early Eocene to Recent (Keen, 1969), but ***Excorbula*** has less discrepant-sized valves, no faint radial ribs on the surface of the left valve, and two keels rather than a single obscure one on the right valve.

The new genus resembles *Notocorbula* Iredale, 1930, which ranges from the Eocene to Recent (Stenzel et al., 1957), but ***Excorbula*** has a more or less quadrate shape; is much more equivalved in terms of size, height, and inflation; has a keel on right valve much nearer posterior dorsal margin; and the dorsal margin is keellike, lacks radial ribs on the left valve, and has a much narrower posterior slope. In addition, ***Excorbula*** has a proportionally lower and less inflated right valve than *Notocorbula.*

The new genus resembles *Jurassicorbula* Fürsich, 1981, a Late Jurassic corbulid, but ***Excorbula*** has a less elongate shape, more equal inflation of the valves, two keels (on the right valve), and no posterior lateral teeth on the right-valve hinge.

Excorbula somewhat resembles *Caryocorbula,* but ***Excorbula*** differs by having a more trigonal shape, valves with discrepant sculpture, two keels, and a groove on the chondrophore rather than a median ridge.

Etymology: The generic name is a combination of the Latin *ex,* meaning from, and *Corbula,* meaning a little basket.

Excorbula coqua Squires & Saul, sp. nov.

(Figures 23–28)

Diagnosis: Small ***Excorbula*** with shell oblong. Commarginal ribs of left valve very weak, but strong on right valve. Posterior slope narrow on right valve.

Description: Shell small (maximum length 9.9 mm). Valves trigonal oblong, tapered posteriorly, moderately inflated, nearly equivalved, and subequilateral. Left valve very slightly smaller than right valve. Anterior end rounded. Posterior end projected into short rostrum. Posterior slope on left valve wide and nearly smooth, set off by low keel. Posterior slope on right valve very narrow, concave, grooved, and set off by two, narrowly spaced keels close to valve margin; one keel emanating from approximately midline of valve and second, stronger "keel" formed by ridge along posterior dorsal margin. Posterior dorsal margin ridge usually widened posteriorly. Umbones moderately high, at midline of valves; beaks prosogyrate, just anterior to midline. Sculpture consisting of commarginal ribs becoming stronger with increased valve

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Figures 21–39. Specimens coated with ammonium chloride. Figures 21, 22. *Caryocorbula* ***louana*** Squires & Saul, sp. nov. Figure 21. Paratype LACMIP 13109, LACMIP loc. 2853, right valve, ×7.8. Figure 22. Paratype SDSNH 81142, SDSNH loc. 3387, dorsal view, ×11.7. Figures 23–28. ***Excorbula coqua*** Squires & Saul, gen. & sp. nov. Figure 23. Paratype LACMIP 13111, LACMIP loc. 8180, left valve, ×9.3. Figures 24, 25. Holotype LACMIP 13110, LACMIP loc. 10884, right valve, ×4.6. Figure 24. Right valve. Figure 25. Oblique view of dorsal margin. Figure 26. Paratype LACMIP 13112, LACMIP loc. 10882, right valve, ×6.2. Figure 27. Paratype LACMIP 13113, LACMIP loc. 10769, immature right valve, ×4.8. Figure 28. Paratype LACMIP 13114, LACMIP loc. 10889, dorsal view, ×6. Figures 29–35. ***Excorbula parkyi*** Squires & Saul, gen. & sp. nov. Figures 29–34. LACMIP loc. 10816. Figure 29. Paratype LACMIP 13115, left valve, ×3. Figures 30, 31. Paratype LACMIP 13116. Figure 30. Left-valve hinge, ×3.3. Figure 31. Left-valve hinge, dorsal view, ×3.8. Figure 32. Holotype LACMIP 13117, right valve, ×2.9. Figure 33. Paratype LACMIP 13118, right valve, oblique view, ×2.9. Figure 34. Paratype LACMIP 13119, right-valve interior, ×2.9. Figure 35. Paratype LACMIP 13120, LACMIP loc. 10787, dorsal view, ×4. Figures 36–39. ***Excorbula shastana*** Squires & Saul, gen. & sp. nov. Figure 36. LACMIP paratype 13121, LACMIP loc. 24648, left valve, ×10.5. Figure 37. LACMIP holotype 13122, LACMIP 24666, right valve, ×5.6. Figure 38. LACMIP paratype 13123, LACMIP loc. 24217, partial right valve, ×6.7. Figure 39. LACMIP paratype 13121, LACMIP loc. 24648, dorsal view. ×10.


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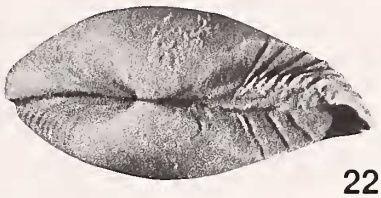
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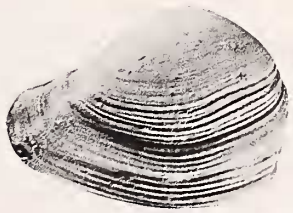
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size. Left-valve sculpture with very weak ribs becoming weak and more widely spaced toward venter, especially antero-ventrally. Right-valve sculpture with very weak closely spaced (7 ribs/mm) commarginal ribs on nepionic cap and becoming medium strength to strong, wavy, and much more widely spaced (2 to 3 ribs/mm) ventrally. Left-valve hinge with slightly projecting chondrophore; adjoining pit deep.

Dimensions of holotype:

Holotype: LACMIP 13110.

Type locality: LACMIP 10884, 33°42′01″N, 117°36′27″W.

Paratypes: LACMIP 13111 to 13114.

Geologic age: Turonian.

Distribution: Redding Formation, Bellavista Sandstone Member, east of Redding, Shasta County, northern California (Figure 1, locale 5); Ladd Formation, Baker Canyon Member, Santa Ana Mountains, Orange County, southern California (type locality) (Figure 1, locale 19).

Discussion: This new species is based on 62 specimens: 48 right valves, 12 left valves, and two pairs of conjoined valves. Only a single specimen (right valve) was found with a predatory drill hole. At LACMIP loc. 10079 in the Baker Canyon Member, the new species co-occurs with a few specimens of *Caryocorbula* ***vacca***.

The new species is most similar to ***Excorbula shastaua***, gen. & sp. nov., but ***E. coqua*** differs by having a more elongate left valve, very weak ribs on the left valve, a narrower distance between the keel and the posterior dorsal margin on the adult right valve, and stronger ribs on the right valve.

Etymology: The specific name *coqua* is Latin, meaning to bake, and refers to the Baker Canyon Member.

Excorbula parkyi Squires & Saul, sp. nov.

(Figures 29–35)

Diagnosis: Medium ***Excorbula*** with shell trigonal. Left valve smooth. Commarginal ribs strong on right valve. Posterior slope very narrow (groovelike) on right valve.

Description: Shell medium (maximum length 15 mm), longer than high. Valves trigonal, equally moderately inflated, nearly equivalved, and nearly equilateral. Left valve slightly smaller than right valve. Anterior and posterior dorsal margins moderately steep and nearly equal. Posterior slope on left valve set off by low keel; posterior slope on some left valves also with weaker radial rib emanating from umbo and continuing to mid portion of posterior margin. Posterior slope on right valve coincident with narrow groove, set off by two, closely spaced keels, of nearly equal strength, and close to margin of valve. One keel emanating from approximate midline of valve; outer keel coincident with ridge on posterior dorsal margin. Umbones moderately high, at midline of valves; beaks prosogyrate, just anterior to midline. Sculpture discrepant on valves. Left valve usually with only prominent growth lines; rarely immature part (nepionic to 2 mm in height) with very weak, closely spaced ribs becoming obsolete ventrally. Right valve with very weak commarginal ribs on immature part (nepionic to 5 mm in height). Ribs on right valve becoming stronger ventrally, with medium strength ribs on early mature part (6 to 8 mm in height) and strong ribs on more mature part; coarse ribs overlapping shinglelike toward umbo and wavy on some specimens and with deep interspaces on ventral part of valve. Left-valve hinge with projecting, broad, chondrophore bearing median groove; adjoining pit triangular and deep. Right-valve hinge with strong central cardinal tooth, curved upward; adjoining pit broad and deep.

Dimensions of holotype: Right valve, 11.4 mm in height, 15 mm in length.

Holotype: LACMIP 13115.

Type locality: LACMIP loc. 10816, 40°38′10″N, 122°6′W.

Paratypes: LACMIP 13116 to 13120.

Geologic age: Coniacian to early Santonian.

Distribution: CONIACIAN: Redding Formation, Bear Creek Sandstone Member and Member IV, east of Redding, Shasta County, northern California (type locality) (Figure 1, locale 5); Chico Formation, Ponderosa Way Member, Chico Creek, Butte County, northern California (Figure 1, locale 7). LOWER SANTONIAN: Redding Formation, Member V, east of Redding, Shasta County, northern California (Figure 1, locale 5).

Discussion: This new species is based on 398 specimens: 282 right valves, 113 left valves, and three pairs of conjoined valves. Many of the single-valved specimens are fragments. Eleven specimens (five left valves and six right valves) show predatory drill holes. The new species is most abundant at the type locality in Oak Run east of Redding, northern California.

The new species resembles *Jurassicorbula edwardi* (Sharpe, 1850:191–192, pl. 21, figs. 2a, b; Fürsich, 1981: 738–739, figs. 1a, b) from Upper Jurassic strata of Portugal and France. The new species differs from *J. edwardi* by having a trigonal-shaped left valve rather than an ellipitical one, equally inflated valves, two keels on right valve and somewhat stronger ribs on the right valve, as well as no lateral teeth on the right-valve hinge.

Excorbula parkyi also resembles ***Pauzacorbula*** *pozo,* but ***E. parkyi*** differs by having a trigonal shape, no deep lunule, no ribs on the left valve, no ribs on the immature part of the right valve, and much weaker ribs on the mature part of the right valve.

Etymology: The species is named for Willis Parkison ("Parky") Popenoe, in recognition of his insightful and careful work on Cretaceous mollusks from the study area.

Excorbula shastana Squires & Saul, sp. nov.

(Figures 36–39)

Diagnosis: Small ***Excorbula*** with shell trigonal to subtrigonal. Left valve smooth. Commarginal ribs on right valve up to medium strength. Posterior slope moderately wide on right valve.

Description: Shell small (maximum 8 mm in length), longer than high. Left valve trigonal ovate; right valve trigonal to subtrigonal, rarely rostrate. Valves nearly equivalved, moderately inflated, right valve more inflated than left valve. Left valve slightly smaller than right valve. Anterior end rounded. Posterior end truncate, or rarely rostrate. Posterior slope of left valve set off by rounded keel. Posterior slope of right valve moderately wide and set off by two low keels, both becoming more distinct ventrally. Ventral-most keel strongest, dorsal-most keel near but not coincident with posterior dorsal margin. Umbones wide and low, at midline of valves; beaks prosogyrate, just anterior to midline. Left valve nearly smooth. Right valve with nearly smooth umbo (occasional minute radial threads), sculpture beginning about just ventral of umbo and consisting of moderately closely spaced (5 ribs/mm), very weak strength commarginal ribs, becoming slightly stronger (weak) and somewhat wavy ventrally.

Dimensions of holotype: Right valve, 5.5 mm in height, 6.8 mm in length.

Holotype: LACMIP 13121.

Type locality: LACMIP 24666, 40°4′23″W, 121°44′38″W.

Paratypes: LACMIP 13122 & 13123.

Geologic age: Late Coniacian to early Campanian.

Distribution: UPPER CONIACIAN: Chico Formation, Ponderosa Way Member, Chico Creek, Butte County, northern California (Figure 1, locale 7). SANTONIAN: Redding Formation, upper part of Member VI, east of Redding, Shasta County, northern California (type locality) (Figure 1, locale 5); Chico Formation, Musty Buck Member, Chico Creek, Butte County, northern California (Figure 1, locale 7). LOWER CAMPANIAN: Chico Formation, Ten Mile Member, Chico Creek, Butte County, northern California (Figure 1, locale 7); Chico Formation, Pentz Road member (informal), near Pentz, Butte County, northern California (Figure 1, locale 8).

Discussion: This new species is based on 121 specimens: 106 right valves, 13 left valves, and two pairs of conjoined valves. Specimens are the most abundant at LACMIP loc. 24648. Three specimens (all right valves) show predatory drill holes.

The new species co-occurs with *Caryocorbula traskii* in the Musty Buck Member, Ten Mile Member, and Pentz Road member.

The new species is most similar to ***E. coqua***, but ***E. shastana*** differs by having a less elongate left valve, no ribs on the left valve, a wider distance between the keel and the posterior dorsal margin on the adult right valve, and weaker ribs on the right valve.

Etymology: The species is named for Shasta County, northern California.

Panzacorbula Squires & Saul, gen. nov.

Type species: ***Panzacorbula*** *pozo* (Dailey & Popenoe, 1966); Late Cretaceous (early late Campanian to early Maastrichtian), southern and south-central California.

Diagnosis: Shell medium, subpryiform to elongate trigonal. Right valve slightly more inflated than left valve. Lunule deep. Commarginal ribs on left valve very weak to weak, and right valve covered with strong ribs. Keel well developed on juveniles, obsolete on mature specimens. Chrondophore inclined and spoon-shaped with long, narrow pit posteriorly adjoining it.

Discussion: The new genus is the only known Cretaceous brackish-marine corbulid from the study area.

The new genus resembles *Indocorbula* Fürsich et al., 2000, from Middle Jurassic strata in western India, but ***Panzacorbula*** differs by having discrepant sculpture; obsolete keel; an inclined, spoon-shaped chondrophre; a long, narrow pit posteriorly adjoining the chondrophore; and no indication of radial ornament.

The new genus somewhat resembles *Ursirivus* Vokes, 1945, from Cenomanian strata of Texas (Stephenson, 1952) and Upper Cretaceous strata of Wyoming and Idaho (Vokes, 1945), but ***Panzacorbula*** differs by being smaller and having a less elongate shape, discrepant inflatedness of the valves, discrepant sculpture, stronger sculpture on the right valve, and the presence of a long, narrow pit posteriorly adjoining the chondrophore.

Etymology: The genus is named for its occurrence in the La Panza Mountain Range, California.

Panzacorbula pozo (Dailey & Popenoe, 1966)

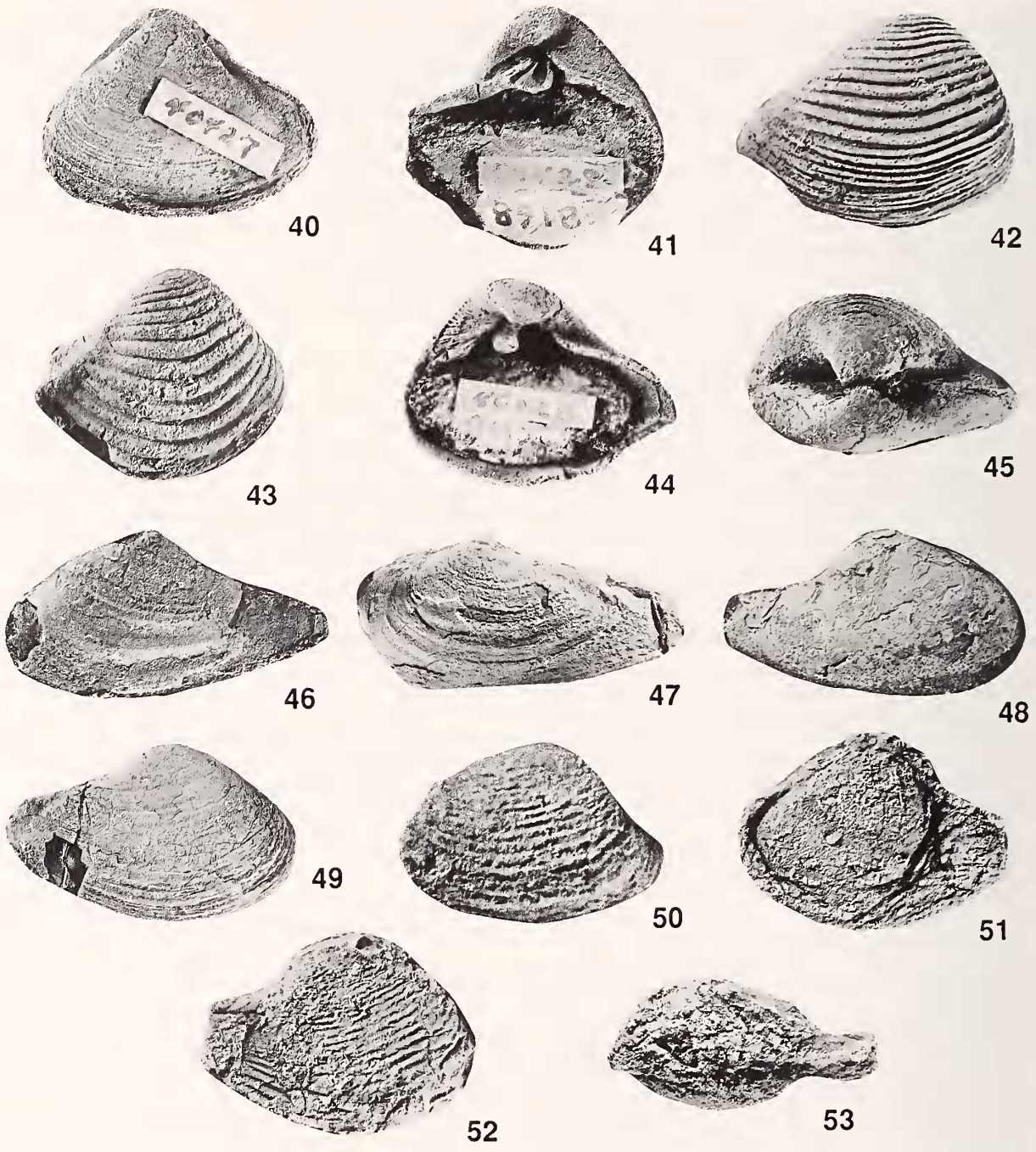
(Figures 40–45)

Corbula pozo Dailey & Popenoe, 1966:19–20, pl. 5, figs. 6–10.

Corbula? sp. aff. *C. pozo* Dailey & Popenoe. Elder et al., 1998:152, pl. 1, fig. 15.

Corbula n. sp. aff. *C. pozo* Dailey & Popenoe. Throckmorton, 1988:pl. 1, fig. 2, table 1.

Corbula sp. Throckmorton, 1988:table 1.



Figures 40–53. Specimens coated with ammonium chloride. Figures 40–45. ***Pauzacorbula*** Squires & Saul, gen. nov. *pozo* (Dailey & Popenoe, 1966). Figure 40. Holotype LACMIP 8916, LACMIP loc. 23774, left valve, ×2.2. Figure 41. Paratype LACMIP 8918, LACMIP loc. 23774, left-valve interior, ×2.1. Figure 42. Paratype LACMIP 8917, LACMIP loc. 23774, right valve, ×2.1. Figure 43. Hypotype LACMIP 13124, LACMIP loc. 10667, immature right valve, ×4.1. Figure 44. Paratype LACMIP 8917, LACMIP loc. 23774, right-valve interior, ×2. Figure 45. Holotype LACMIP 8916, LACMIP loc. 23774, dorsal view, ×2. Figures 46–49. *Eoursivivas cultriformis* (Gabb, 1864). Figure 46. Hypotype LACMIP 13125, LACMIP loc. 26345, left valve, ×2.6. Figure 47. Hypotype LACMIP 13126, LACMIP loc. 26345, left valve, ×5.1. Figure 48. Lectotype UCMP 11945a, CGS loc. 144, right valve, ×5.2. Figure 49. Hypotype LACMIP 13127, LACMIP loc. 26345, right valve, ×2.3. Figures 50–53. *Caestocorbula* ***cavus*** Squires & Saul, sp. nov., UCMP loc. B-5611. Figure 50. Paratype UCMP 155540, left valve, ×13.7. Figures 51–53. Holotype UCMP 155539, ×7. Figure 51. Left valve. Figure 52. Right valve. Figure 53. Dorsal view.

Diagnosis: Same as for genus.

Description: Shell medium (maximum length 21.7 mm); moderately thick. Valves subpyriform to trigonal elongate, inflated (right valve more inflated than left valve), nearly equilateral (left valve very slightly smaller than right valve), sub-inequilateral. Lunule deep; escutcheon less well developed. Anterior and posterior ends rounded. Posterior end of both valves projected, set off by subdued, very low keel on left valve and sharp keel on juvenile right valve; keel becoming obsolete with growth on both valves. Umbones moderately high, at midline of valves or slightly anterior of midline; beaks prosogyrate, just anterior to midline. Left valve nearly smooth on umbo but with very weak to weak, closely spaced ribs toward venter. Right valve with strong, widely spaced wavy ribs, overlapping shinglelike toward umbo, and with deep interspaces. Ribs on both valves gradually becoming obsolete posteriorly, producing smooth posterior slope. Left-valve hinge with thickened lunular margin (which fits into narrow antecardinal socket in right valve), somewhat narrow V-shaped socket, and large spoon-shaped chondrophore with edges delimited by ridges. Chondrophore projecting beyond plane of commissure and aligned at an angle of approximately 45° to it. Pit posteriorly adjoining chondrophore V-shaped, long, narrow, and deep. Right-valve hinge with narrow antecardinal socket; single, large triangular cardinal tooth; adjoining pit trigonal, broad, and deep. Cardinal tooth situated below and slightly anterior to beak to which it is joined by narrow ridge.

Dimensions of holotype: Conjoined valves, 15 mm in height, 21.7 mm in length, 11.2 mm in thickness.

Holotype: LACMIP 8916 (= ex UCLA 40427).

Type locality: LACMIP loc. 23774.

Paratypes: LACMIP 8917 and 8918 (= ex UCLA 40428 and 40429).

Geologic age: Early late Campanian to early late Maastrichtian.

Distribution: LOWER UPPER CAMPANIAN: Jalama Formation, Santa Barbara County, southern California (Figure 1, locale 17). UPPER CAMPANIAN/LOWER MAASTRICHTIAN UNDIFFERENTIATED: Gualala Formation, Anchor Bay Member, Mendocino County, northern California (Figure 1, locale 10); unnamed Cretaceous formation, Pozo district, San Luis Obispo, central California (type locality) (Figure 1, locale 16). LOWER MAASTRICHTIAN: Tesla Formation, near base of lower sandstone member, Corral Hollow, east of Livermore, Alameda County, western edge of San Joaquin Valley, central California (Figure 1, locale 12). UPPER LOWER TO LOWER UPPER MAASTRICHTIAN: Moreno Formation, Tierra Loma Member, Ortigalita Creek, south of Los Banos Reservoir, Merced County, west side of San Joaquin Valley, central California (Figure 1, locale 14).

Discussion: This study of Dailey and Popenoe's species is based on 124 specimens (including the type material): 96 right valves, 25 left valves, and three pairs of conjoined valves. Only one specimen (right valve) has a predatory drill hole. There can be some variation in the strength of the ribs. At UCMP locs. D-8149 and D-8174, near the base of the lower sandstone member of the Tesla Formation, some right valves have weaker ribs than normal.

The overall shell shape and lunule depth of ***Panzacorbula*** *pozo* is remarkably similar to *Indocorbula basseae* (Singh & Rai, 1980:79, pl. 1, fig. 6a; Fürsich et al., 2000: 142, pl. 17, figs. 14, 15, pl. 18, figs. 8, 9) from Middle Jurassic strata of western India. ***Panzacorbula*** *pozo* differs from the Indian species by having an inclined, spoon-shaped chondrophore (rather than a flattish one) and valves with significantly discrepant sculpture. Both valves of *I. basseae* have coarse ribs.

Panzacorbula *pozo* strongly resembles *Caryocorbula? ovisana* Stephenson (1952:129, pl. 32, figs. 9–15) from Cenomanian strata of Texas, but ***P.*** *pozo* differs by having a less trigonal shape and a weaker keel on both valves. In addition, on the left valve of ***P.*** *pozo*, the socket that accommodates the right-valve cardinal tooth is much narrower and V-shaped, rather than wide-oval.

Panzacorbula *pozo* resembles somewhat ***Excorbula parkyi***, but ***P.*** *pozo* differs by having a subpyriform shape, lunule, ribs on the left valve, ribs on the immature part of the right valve, and much stronger ribs on the mature part of the right valve.

Genus *Eoursivivas* Ota, 1964

Type species: *Corbula matsumotoi* Hase, 1960, by original designation; Early Cretaceous (Valanginian to Hauterivian), Japan.

Diagnosis: Shell medium, very elongate to subpyriform. Sculpture consisting of subdued, irregular bands. Keel weak to moderately well developed, with groove between it and posterior dorsal margin.

Discussion: *Eoursivivas* Ota, 1964, was previously known only from Lower Cretaceous (Valanginian to Hauterivian) strata of Japan. *Eoursivivas cultriformis* is the first record of this genus in the Western Hemisphere and its youngest record.

Eoursivivas cultriformis (Gabb, 1864)

(Figures 46–49)

Corbula cultriformis Gabb, 1864:149, pl. 22, figs. 122.

Corbula (*Anisorhynchus*) *cultriformis* (Gabb). Dall, 1898: 840.

Corbula cultriformis Gabb. Stewart, 1930:289.

Diagnosis: An *Eoursivivas* with subdued irregular com-

marginal bands. Keel low. Posterior slope slightly concave.

Description: Shell medium (maximum 20 mm in length). Valves very elongate, nearly equivalved, and inequilateral. Anterior end rounded. Posterior end considerably elongate, somewhat oblong. Anterior dorsal margin somewhat steeper than posterior dorsal margin. Posterior slope slightly concave and set off by low keel, situated very near valve edge. Posterior dorsal margin somewhat prominent on some specimens, thereby producing second keel. Umbones moderately low, slightly anterior of midline of valves; beaks approximately 39% of the distance from the anterior end. Lunule and escutcheon absent. Sculpture on both valves consisting of rather weakly developed commarginal ribs, occurring as irregular bands. Left-valve hinge with projecting chrondrophore.

Dimensions of lectotype: Right valve, 4.9 mm in height, 9 mm in length.

Lectotype: UCMP 11945a [= CGS 144], designated here.

Type locality: Exact location unknown, Martinez, Contra Costa County, northern California.

Geologic age: Late early to early late Maastrichtian.

Distribution: UPPER LOWER TO LOWER UPPER MAASTRICHTIAN: Moreno Formation, Tierra Loma Member, Ortigalita Creek, south of Los Banos Creek Reservoir, Merced County, west side of San Joaquin Valley, central California (Figure 1, locale 14). MAASTRICHTIAN UNDIFFERENTIATED: Great Valley Series, near Martinez, northern California (type locality) (Figure 1, locale 11).

Discussion: This study of Gabb's species is based on 35 specimens (including Gabb's syntypes): 22 right valves and 13 left valves. No conjoined valves were detected. Only one specimen (right valve) has a predatory drill hole. Most of the specimens are weathered, and on those with severe weathering, the growth bands become riblike.

Stewart (1930:289) reported that the type material of this species should be at UCMP, and that one of these specimens is UCMP specimen 11945a. Our search of this collection resulted in the detection of two cabinets containing Gabb's material formerly stored under the auspices of the old California Geological Survey (CGS) collection. A box labelled "CGS no. 144, original material," contains seven specimens of *Corbula cultriformis,* and one of these is labelled 11945a. All of these specimens are poorly preserved internal molds, external molds, or have retained only a portion of their shell. Because Gabb did not designate a holotype, we select specimen 11945a, which has some of its shell intact (Figure 48), to serve as the lectotype.

Eoursivivas cultriformis is most similar to *Eoursivivas matsumotoi* (Hase, 1960:332, pl. 39, figs. 5–21; Ota, 1964:155–157, pl. 21, figs. 1–11, text fig. 4; Hayami, 1975:146, pl. 10, figs. 7, 8; Tashiro, 1992:pl. 74, fig. 2) from Lower Cretaceous (Valanginian to Hauterivian) strata of Japan. *Eoursivivas cultriformis* differs from *E. matsumotoi* by having a slightly better developed keel and a slightly concave posterior slope.

Subfamily Caestocorbulinae Vokes, 1945

Genus *Caestocorbula* sensu lato Vincent, 1910

Type species: *Corbula henckeliusiana* Nyst, 1836, by original designation; Eocene, Belgium.

Diagnosis: Shell small to moderate, subtrigonal, moderately inflated, and inequivalved. Left valve usually much smaller, less inflated, less rostrate, and with generally weaker commarginal ribs than on right valve. Accessory siphonal plate of left valve rectangular, with faint median groove, and fitting into rostrum of right valve. Left valve lacking all trace of posterior elongation. Left-valve hinge with projecting chondrophore. Right valve produced posteriorly into a prominent rostral "snout." Right cardinal tooth relatively large and heavy. Pallial sinus extremely well developed (Vokes, 1944, 1945; Keen, 1969).

Discussion: Vokes (1945) provided taxonomic details and a detailed description of the genus.

Caestocorbula (*Caestocorbula*) Vincent, 1910, is very similar to *Caestocorbula* (*Parmicorbula*) Vokes, 1944. Fossil specimens of *Caestocorbula* are virtually indistinguishable from *Parmicorbula,* unless their accessory siphonal plate posterior to the right valve is preserved; however, the siphonal plate is rarely found on fossil specimens. For both of the new species described below, no information is known about the accessory siphonal plates; hence, *Caestocorbula* sensu lato is used.

The earliest records of *Caestocorbula* sensu stricto are *Caestocorbula morinoi* Tashiro & Kozai, 1991, from either Lower Cretaceous (Valanginian or Barremian) strata in Japan, and *Caestocorbula antiqua* Kozai, 1987, from Lower Cretaceous (either upper Hauterivian or Barremian) strata in Japan. The earliest record of *Parmicorbula* is *Parmicorbula neaeroides* (Blanckenhorn, 1890) from Aptian (undifferentiated) rocks in Lebanon and Syria (Vokes, 1944, 1945; Keen, 1969). Tashiro & Kozai (1991) tentatively reported *Parmicorbula* from lower Aptian strata in Japan. According to Keen (1969), *Caestocorbula* and *Parmicorbula* both went extinct in the Eocene.

Caestocorbula ***cavus*** Squires & Saul, sp. nov.

(Figures 50–53)

Diagnosis: Small *Caestocorbula* with both valves ovate. Commarginal ribs on left valve uniformly very weak, those on right valve uniformly weak.

Description: Shell small (maximum length 9 mm), longer than high. Valves ovate, slightly inflated, and inequilateral. Left valve smaller than right valve. Anterior end rounded. Posterior dorsal part of left valve deeply indented and concave, passing into short rostrum. Posterior slope of left valve with very low to obscure keel. Posterior end of right valve with projected rostal "snout." Umbones central. Sculpture on left valve consisting of moderately closely spaced, uniformly very weak commarginal ribs. Sculpture on right valve consisting of moderately closely spaced, uniformly weak ribs, becoming slightly more widely spaced ventrally.

Dimensions of holotype: Conjoined valves, 4 mm in height, 6 mm in length, 1.8 mm in thickness.

Holotype: UCMP 155539.

Type locality: UCMP B-5611, 31°28′N, 116°36′30″W.

Paratype: UCMP 155540.

Geologic age: Late Aptian.

Distribution: Alisitos Formation, upper member, Arroyo de la Cueva, just southeast of Punta China, northwestern Baja California, Mexico (Figure 1, locale 21).

Discussion: This new species is based on 13 specimens: nine right valves, three pairs of conjoined valves, and one left valve. All are from the type locality, and they are somewhat poorly preserved. Some seem to have been distorted by crushing. The adult left valve of this species is not well known. The best preserved left valve is that of a very early juvenile (Figure 50). The left valve of the holotype is an adult but is poorly preserved (Figures 51–53).

The new species is assigned to *Caestocorbula* based on the projected rostral "snout" of the right valve apparently extending farther than the short rostrum on the left valve.

Caestocorbula ***cavus*** is most similar to *Caestocorbula* (s. l.) *ohtai* Kozai (1987:329–330, fig. 3–12-20) from Cenomanian strata of Japan. The new species differs from *C. ohtai* by having an ovate left valve and ribbing that does not curve dorsally on the anterior part of the left valve.

Etymology: The species is named for its occurrence in Arroyo de la Cueva (Spanish for cave), Baja California, Mexico; Latin, *cavus* meaning cave.

Caestocorbula ***attina*** Squires & Saul, sp. nov.

(Figures 54–57)

Diagnosis: Very small *Caestocorbula* with left valve triangular, right valve subtrigonal. Commarginal ribs on left valve very weak, irregularly spaced; those on right valve very weak to weak, prominent, and with deep interspaces; ribs on right valve becoming stronger ventrally.

Description: Shell very small (maximum length 5.5 mm), higher than long. Left valve smaller and less inflated than right valve. Left valve triangular, lowly inflated, umbones at midline of valves. Right valve subtrigonal, prominently inflated; anterior margin broadly rounded; posterior end produced into "spout-like" rostration. Posterior slope of right valve nearly vertical and set off by straight keel, causing wrinkles in adjacent ornament. Umbo of right valve broadly rounded and low, at midline of valve; beak prosogyrate. Left valve smooth on umbo, sculpture consisting of very weak commarginal ribs, irregularly spaced. Right-valve sculpture prominent, consisting of very weak to weak commarginal ribs, becoming stronger toward ventral margin; interspaces consistently deep.

Dimensions of holotype: Right valve, 4.5 mm in height, 5.5 mm in length.

Holotype: LACMIP 13128.

Type locality: LACMIP loc. 25526, 35°54′48″N, 120° 09′05″W.

Paratypes: LACMIP 13129 and CAS 69098.02.

Geologic age: Cenomanian.

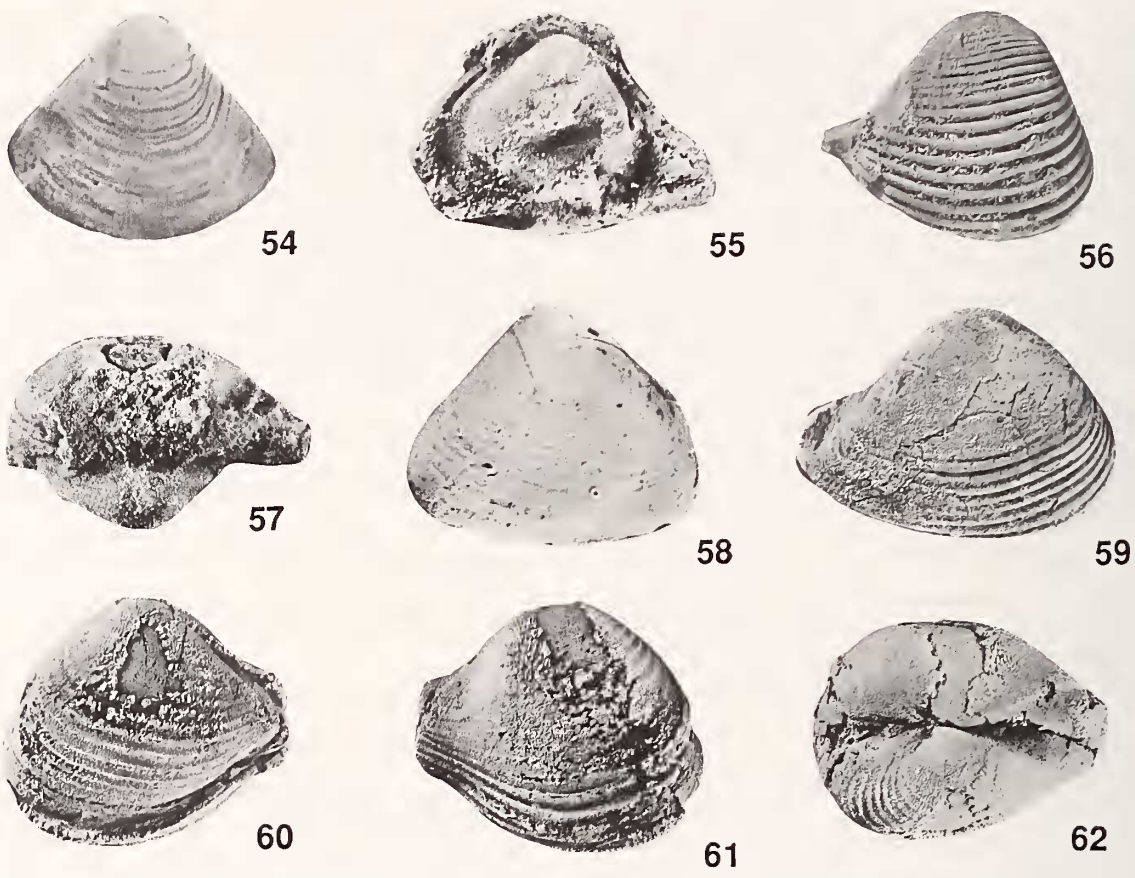
Distribution: LOWER CENOMANIAN: Unnamed strata near Dayville, Grant County, Oregon (Figure 1, locale 2). UPPER CENOMANIAN/LOWER TURONIAN: Panoche Formation at Reef Ridge, Kings County, central California (type locality) (Figure 1, locale 15). CENOMANIAN UNDIFFERENTIATED: Budden Canyon Formation, Bald Hills (upper part), Bald Hills near Ono, Shasta County, northern California (Figure 1, locale 4).

Discussion: This new species is based on 36 specimens: 28 right valves, six left valves, and two pairs of conjoined valves. All but three of the specimens are from the type locality, where preservation is good, although some specimens found there are fragments. Although the specimens are slightly larger at LACMIP loc. 9936 in Grant County, Oregon, the preservation there is poor. This latter locality is discussed by Squires & Saul (2002).

The new species is similar to *Caestocorbula henckeliusiana* (Nyst, 1836:4, pl. 1, figs. 8a,b; Vokes, 1994:pl. 1, figs. 1–3; Vokes, 1945:20–21, pl. 4, figs. 1–4; Keen, 1969:fig. 158,6), the type species of the genus, but the new species differs by having a greater height to length ratio and coarser sculpture.

The right valve of the new species is very similar to *Caestocorbula*? ***allisoni*** sp. nov., but the new species differs from *C.* ? ***allisoni*** by having a left valve that is nearly triangular, less inflated, much smaller than the right valve, and with much weaker commarginal ribs.

Etymology: The species is named for its occurrence in the Reef Ridge area; Latin, *attina* meaning stonewall.



Figures 54–62. Specimens coated with ammonium chloride. Figures 54–57. *Caestocorbula* ***attina*** Squires & Saul, sp. nov. Figure 54. Paratype LACMIP 13129, LACMIP loc. 25526, left valve, ×8. Figure 55. Paratype CAS 69098.02, CAS loc. 69098, left valve, ×10.4. Figure 56. Holotype LACMIP 13128, LACMIP loc. 25526, right valve, ×6.9. Figure 57. Paratype CAS 69098.02, CAS loc. 69098, dorsal view, ×10.4. Figures 58–59. *Caestocorbula* ***aura*** Squires & Saul, sp. nov. Figure 58. CAS paratype 69106.05, CAS loc. 69106, left valve, ×7. Figure 59. CAS holotype 69106.01, CAS loc. 69106, right valve, ×6. Figures 60–62. *Caryocorbula*? ***allisoni*** Squires & Saul, sp. nov., holotype UCMP 155541, UCMP loc. A-9521, ×5.4. Figure 60. Left valve. Figure 61. Right valve. Figure 62. Dorsal view.

Caestocorbula ***aura*** Squires & Saul, sp. nov.

(Figures 58,59)

Diagnosis: Small *Caestocorbula* with both valves trigonal. Commarginal ribs on left valve weak, and flattish. Umbo of right valve smooth; ventrally of umbo, ribs weak, rounded, and prominent.

Description: Shell small (maximum 7 mm in length), longer than high. Valves trigonal, moderately inflated, and equilateral. Posterior slope of left valve set off by very weak barely discernible keel. Left valve rostrate. Right valve with moderately long, projected rostrum; longer than that on left valve. Posterior slope of right valve slightly concave, moderately long, ribbed, and set off by low keel. Umbones moderately high and near midline of valves; beaks prosogyrate. Left-valve sculpture consisting of flattish, weak commarginal ribs overlapping shingle-like and moderately widely spaced (approximately 3 ribs/mm). Right valve usually smooth on umbo, with sculpture beginning near medial part of valve and consisting of moderately closely spaced (approximately 4 ribs/mm), rounded, weak commarginal ribs with moderately deep interspaces. Ribs on right valve becoming stronger and more widely spaced ventrally. Left-valve hinge with posteriorly directed chondrophore with median groove. Right-valve hinge with single cardinal tooth, posteriorly adjoining pit deep. Pallial line simple, well incised, and nearly vertical posteriorly.

Dimensions of holotype: Right valve, 4.9 mm in height, 6.6 mm in length.

Holotype: CAS 69106.05.

Type locality: CAS loc. 69106, 40°23′40″N, 122°32′15″W.

Paratype: CAS 69106.01.

Geologic age: Turonian.

Distribution: Budden Canyon Formation, lower part of Gas Point Member, near Ono, Shasta County, northern California (Figure 1, locale 4).

Discussion: This new species is based on 104 specimens: 76 right valves and 28 left valves. No conjoined valves were found. Specimens are most abundant at the type locality. Only a single specimen (right valve) has a predatory drill hole.

The new species is most similar to *Caestocorbula* ***attina*** but differs from *C.* ***attina*** by usually having no ribs on the umbo of the right valve, more closely spaced ribs on the right valve, better defined ribs on the left valve, and a less symmetrical left valve.

Etymology: The species is named for its occurrence in the Gas Point Member; Latin, *aura* meaning wind (gas).

Caestocorbula? ***allisoni*** Squires & Saul, sp. nov.

(Figures 60–62)

Diagnosis: Small *Caestocorbula*? with both valves bulbous. Commarginal ribs on left valve medium, those on right valve weak to medium, becoming slightly stronger ventrally.

Description: Shell small (maximum 7 mm in length), higher than long. Valves bulbous, rounded, and strongly inflated. Left valve smaller than right valve. Valves inequilateral, plump centrally and anteriorly; posterior ends constricted and, especially right valve, with projected rostrum extending from medial part of valve. Rostrum on right valve extending beyond end of rostrum on left valve. Posterior slope of right valve smooth, moderately steep, and set off by moderately low, straight keel. Umbones moderately high and at midline of valves; beaks prosogyrate. Sculpture of left valve consisting of moderately widely spaced, medium-strength commarginal ribs. Sculpture of right valve consisting of weak to medium-strength commarginal ribs, becoming slightly stronger ventrally. Right-valve hinge with single, large triangular cardinal tooth; adjoining pit broad and deep.

Dimensions of holotype: Conjoined-valved specimen, 8.1 mm in height, 7 mm in length, 5.1 mm in thickness.

Holotype: UCMP 155541.

Type locality: UCMP loc. A-9521, 31°30′N, 116°40′W.

Geologic age: Late Aptian.

Distribution: Alisitos Formation, upper member, Punta China, northwestern Baja California, Mexico (Figure 1, locale 21).

Discussion: This new species is based on three specimens: two pairs of conjoined valves and one right valve.

The left valve of the holotype of the new species is complete, and the posterior end of the right valve, which is broken, originally extended beyond (how much is unknown) the limit of the left valve. One of the other specimens borrowed from the UCMP collection had been cut in half, parallel to the hinge, thereby revealing the presence of the cardinal tooth.

The new species seems to be assignable to *Caestocorbula* based on the sharply constricted posterior parts of the valves. Unlike *Caestocorbula,* however, it has equally inflated valves with non-discrepant sculpture; hence, the new species is tentatively assigned to this genus. Future studies might show that *C.*? ***allisoni*** belongs to a new genus.

Caestocorbula? ***allisoni*** is most similar to *Corbula* sp. Woods (1908:213, pl. 34, fig. 13) from the Aptian to lower Albian Lower Greensand in England. The new species differs by having slightly narrower commarginal ribs on the right valve. The left valve of this English species is not known. *Corbula* sp. Woods might belong to *Parmicorbula,* but information about the left valve must be obtained before making this assignment.

The new species is similar to *Parmicorbula rupana* Stephenson (1952:133, pl. 33, figs. 9–12) from the Cenomanian Woodbine Formation of central and northeastern Texas. The new species differs from Stephenson's species by having a more rounded shape, especially the left valve, and somewhat stronger commarginal ribs.

Etymology: The species is named for the late E. C. Allison, in recognition of his paleontological work in Baja California.

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APPENDIX

LOCALITIES CITED

Localities are LACMIP, unless otherwise indicated. All quadrangle maps listed below are U. S. Geological Survey maps.

CAS 69098. [= LACMIP 23476]. Hard concretionary sandstone in first large creek (Coyote Creek) N of Crow Creek, section 30, T. 30 N, R. 6 W, Ono Quadrangle (15 minute, 1952), Shasta County, northern California. Budden Canyon Formation, Bald Hills Member (upper part). Age: Cenomanian. Collector: P. Rodda, August, 1955.

CAS 69106. [= LACMIP 23950]. Gray mudstone in N bank of Roaring River, 610 m N and 732 m W of SE corner of section 4, T. 29 N, R. 6 W, Ono Quadrangle (15 minute, 1952), Shasta County, northern California. Budden Canyon Formation, Gas Point Member (lower part). Age: Turonian. Collectors: W. P. Popenoe & W. A. Findley, 1933.

CAS 69109. [= LACMIP 23768]. Hard pebbly sandstone in creek on E side of old Gas Point Road, 472 m S and 610 m E of NW corner of section 16, T. 30 N, R. 6 W, Ono Quadrangle (15 minute, 1952), Shasta County, northern California. Budden Canyon Formation, Bald Hills Member (upper part). Age: Cenomanian. Collector: P. Rodda, August, 1956.

2853. Broken concretion with numerous fossils, just S of Arroyo Tiburon (a tributary on W side of Arroyo Santa Catarina). Near mouth of and along W side of Arroyo Santa Catarina, SE side of Mesa San Carlos, northern Baja California, Mexico. Rosario Formation. Age: Late Campanian to early Maastrichtian. Collector: M. L. Webster, 1966.

7792. At Carlsbad Research Center north of Palomar Airport, near some claypits south of Letterbox Canyon, 5 m above base of temporary cut bank, N side of Faraday Ave., E of intersection with Rutherford Road, approximately 1088 m N, 2966 m W of SE corner of San Luis Rey Quadrangle (7.5 minute, 1968), San Diego County, southern California. Point Loma Formation. Age: Late Campanian to early Maastrichtian. Collector: J. D. Loch.

8180. Concretions in shale just above sandstone on S side of Silverado Canyon, 121m N and 61 m E of SW corner of section 9, T. 5 S, R. 7 W, Santiago Peak Quadrangle (7.5 minute, 1954), Santa Ana Mountains, Orange County, southern California. Ladd Formation, Baker Canyon Member. Age: Turonian. Collector: B. N. Moore, 1928.

9936. Fossiliferous brown sandstone about 4.5 km (2.8 mi.) S of U. S. Highway 26, along W side of Bridge Creek, 610 m N and 805 E of SW corner of section 25, T 13 S, R 27 E, Aldrich Mtn. North Quadrangle (7.5 minute, 1972; photorevised 1983), Grant County, east-central Oregon. Unnamed strata. Lower Cenomanian. Collectors: W. P. Popenoe and J. Alderson, June 12, 1975. [Locality is same as LACMIP locality 28787].

10667. On ridge just above creek bed and near base of sandstone, 853 m S and 1,371 m E of NW corner of section 33, T. 11 S, R. 10 E, Ortigalita Peak NW Quadrangle (7.5 minute, 1969; photorevised, 1984), Merced County, California. Moreno Formation, Tierra Loma Member. Age: Late early to early late Maastrichtian. Collector: B. C. Adams, August, 1941.

10764. [= CIT 1466]. Concretion in sandstone near top of N slope of hillside about 0.4 km S of Alturas-Redding Highway, about 0.2 km W of middle of E line of section 35, T. 33 N, R. 3 W, Redding Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Bella Vista Sandstone Member. Age: Turonian. Collector: W. P. Popenoe, March 23, 1940.

10769. Small lens in massive sandstone outcropping in bed of Dry Creek, about 0.2 km S of line between townships 32 and 33N, 1463 m N6°40'W from SE corner of section 6, T. 32 N, R. 3 W, Redding Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Bella Vista Sandstone Member. Age: Turonian. Collectors: W. P. Popenoe & C. Ahlroth, June 23, 1936.

10787. Near crest of N slope of divide between Basin Hollow and Clover Creek, no more than 122 m S of section line, near NE corner of NW 1/4 of section 33, T. 32 N, R. 2 W, Redding Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, lower part Member V (of Popenoe, 1943). Age: Early Santonian. Collectors: W. P. Popenoe & D. W. Scharf, August 8, 1931.

10816. [= CIT 1007]. Hard limy sandstone outcropping on lower slope of hills N of Oak Run, approximately 0.4 km S26°E of NW corner of section 16, T. 32 N, R. 2 W, Millville Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Member IV. Age: Coniacian. Collectors: W. P. Popenoe & D. W. Scharf, Aug. 9, 1931.

10832. [= CIT 1012]. Beds of small gullies in the field on both sides of the E-W highway connecting Pentz and Chico, about 1.3 km N86°W of Pentz, NW/4, NW/4 of section 25, T. 21 N, R. 3 E (Cherokee Quadrangle, 7.5 minute, 1949), Butte County, northern California. Chico Formation, Pentz Road member (informal). Age: Early Campanian. Collectors: W. P. Popenoe & D. W. Scharf, August, 15, 1931.

10882. Just N of Silverado Canyon, 838 m N and 69 m E of NW corner of section 8, T. 5 S, R. 7 W, Black Star Quadrangle (7.5 minute, 1967), Santa Ana Mountains, Orange County, southern California. Ladd Formation, Baker Canyon Member. Age: Turonian. Collector: W. P. Popenoe, May 19, 1934.

10884. [= CIT 978]. Sandstone about 46 m above top of gray basal Cretaceous conglomerate, approximately 2.4 km SE of dam just above mouth of Harding Canyon, NE slope and near crest of bluff overlooking Santiago Canyon at about the NE corner of section 33, T. 5 S, R. 7 W, Santiago Peak Quadrangle (7.5 minute, 1954), Santa Ana Mountains, Orange County, southern California. Ladd Formation, Baker Canyon Member. Age: Turonian. Collector: W. P. Popenoe, April 14, 1933.

10889. Conglomerate lens in shale 122 m above creek W of fork of Harding and Santiago creeks, Santa Ana Mountains, Orange County, southern California. Ladd Formation, Baker Canyon Member. Age: Turonian. Collector: W. P. Popenoe, August, 1929.

11965. [= SDSNH 3457]. At Carlsbad Research Center north of Palomar Airport, in temporary exposures of shale S of Letterbox Canyon, along Faraday Ave., San Luis Rey Quadrangle (7.5 minute, 1975 provisional edition), San Diego County, southern California. Point Loma Formation. Age: Late Campanian to early Maastrichtian. Collector: B. O. Riney, September 8, 1987.

22406. Gullies on both sides of highway approximately 0.8 km due W of Pentz, California. Cherokee Quadrangle (7.5 minute, 1949), Butte County, northern California. Chico Formation, Pentz Road member (informal). Age: Early Campanian. Collector: W. P. Popenoe, July 18, 1946.

23774. At waterfall in NNW-trending canyon, E of Toro Creek, SE/4 of section 6 and NE/4 of section 7, T. 30 S, R. 15 E, Pozo Quadrangle (15 minute, circa 1952), San Luis Obispo County, central California. Unnamed Upper Cretaceous formation. Age: Late Campanian and/or early Maastrichtian. Collectors: W. Waisgerber, R. W. Imlay & W. P. Popenoe.

24217. Hard sandstone slabs in bed of Clover Creek, 213 m N and 366 m W of SE corner of section 22, T. 32 N, R. 2 W. Member VI of Popenoe (1934). Age: Late Santonian. Collectors: W. P. Popenoe & D. H. Dailey, August 27, 1959.

24285. From calcareous slump blocks in shale, S slope of hill at about 304 m (1000 ft.) contour, on E side of Antelope Creek Valley, NW/4, SW/4 of section 5, T. 16 N, R. 4 W, about 4.5 km due S of Sites, Lodoga Quadrangle (15 minute, 1943), Colusa County, northern California. Cortina formation (informal), Turonian Venado Sandstone Member (basal part) containing reworked late Albian fossils. Collector: T. Harding.

24365. In fine-grained sandstone with ammonite *Romaniceras,* left bank of French (Swede) Creek, approximately 152 m N and W of SE corner of section 5, T. 32 N, R. 2 W, Millville Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Frazier Siltstone Member. Age: Turonian. Collector: W. P. Popenoe, August 25, 1957.

24648. Thin sandstone lentils in siltstone, N side of South Cow Creek Valley, approximately 244 m S and 396 m E of NW corner of section 12, T. 31 N, R. 2 W, Millville Quadrangle (15 minute, 1953). Redding Formation, Member VI of Popenoe (1943). Age: Santonian. Collector: W. P. Popenoe.

24666. Small canyon on N side of Deer Creek, 229 m S and 686 m W of NE corner of section 27, T. 26 N, R. 2 E, Butte Meadows Quadrangle (15 minute, 1958), Tehama County, northern California. Chico Formation, ?Ten Mile Member. Age: Santonian. Collector: P. Rodda, July, 1954.

25526. On ridge with conglomerate beds just E of the Big Tar Canyon Road, 887 m N and 518 m W of SE corner of section 20, T. 23 S, R. 17 E, Garza Peak Quadrangle (7.5-minute, 1953), Reef Ridge area, Kings County, central California. Panoche Formation. Age: Late Cenomanian to early Turonian clasts in a Campanian conglomerate. Collector: E. V. Tamesis, early 1960s.

26345. Approximately 3.2 km S of Ortigalita Creek, 975 m N and 1417 m E of SW corner of section 33, T. 11 S, R. 10 E, Ortigalita Peak NW Quadrangle (7.5 minute, 1969, photorevised 1984), Merced County, central California. Moreno Formation, Tierra Loma Member. Age: Late early to early late Maastrichtian. Collectors: R. B. Stewart & W. P. Popenoe, 1944.

29230. Sandstone cropping out in gully W of first ridge W of road along N-S boundary between section 28 and 29, T. 31 N, R. 5 W, 305 m N, 229 m W of SE corner of the Redding Quadrangle (15 minute, 1946), Texas Springs, Shasta County, northern California. Budden Canyon Formation, Chickabally Member. Age: Late early Albian. Collector: W. P. Popenoe, August 29, 1960.

SDSNH 3162-C. Elevation 85 m, in sandy mudstone, in a sewer-line trench now covered by Faraday Avenue, at Carlsbad Research Center, S of Letterbox Canyon and N of Palomar Airport, San Luis Rey Quadrangle (7.5 minute, 1968, photorevised 1975), Carlsbad area, northern San Diego County, southern California. Point Loma Formation. Age: Late Campanian to early Maastrichtian. Collectors: B. O. Riney & T. A. Demere, March 1 to May 16, 1982.

SDSNH 3387. Elevation 53 m, in silty shale, in a temporary exposure along W side of College Boulevard, extending from El Camino Real S for 457 m, NW of Palomar Airport, San Luis Rey Quadrangle (7.5 minute, 1968, photorevised 1975), San Diego County, southern California. Point Loma Formation. Age: Late Campanian to early Maastrichtian. Collectors: M. A. Roeder & R. Q. Gutzler, December 1, 1986.

UCMP A-6273. South side of Río de Santo Tomás, just N of Punta China, northwestern Baja California, Mexico. Alisitos Formation, upper member. Age: Late Aptian. Collectors: Kirk & McIntyre, 1951.

UCMP A-9521. Punta China, northwestern Baja California, Mexico. Alisitos Formation, upper member. Age: Late Aptian. Collector: E. C. Allison.

UCMP B-5611. From top of argillaceous unit immediately below caprinid-rudist-bearing limestone, Arroyo de la Cueva, 8.25 km SE of Punta China, northwestern Baja California, Mexico. Alisitos Formation, upper member. Age: Late Aptian. Collector: E. C. Allison, June, 1951.

UCMP D-8149. Fine-grained sandstone in roadcut on W side of dirt road on W band of a N-sloping ravine, NE/4 of section 32, T. 3 S, R. 4 E, Midway Quadrangle (7.5 minute, 1953), Corral Hollow area, Alameda County, north-central California. Tesla Formation, near base of lower sandstone member. Age: Early Maastrichtian. Collector: C. K. Throckmorton, 1981.

UCMP D-8174. Gray silty mudstone, on E bank of Mitchell Ravine, NW 1/4 of section 31, T. 3 S, R. 4 E, Midway Quadrangle (7.5 minute, 1953), Corral Hollow area, Alameda County, north-central California. Tesla Formation, near base of lower sandstone member. Age: Early Maastrichtian. Collector: C. K. Throckmorton, 1980.

USGS M-175. Calcareous fine- to medium-grained sandstone, 61 m E of the SW corner of section 33, T. 18 N, R. 4 W, 2012 m S of point "1009 ft" on Logan Ridge, Lodoga Quadrangle (15 minute, 1943), Colusa County, northern California. Upper part of Antelope Shale, stratigraphic unit 7c of Brown and Rich (1961) and approximately 23 to 30 m below base of Venado Sandstone Member of Cortina formation (informal). Cenomanian. Collectors: R. D. Brown, Jr. & E. I. Rich, 1958.

USGS M-176. Pebbly deformed mudstone, on Logan Ridge, 640 m N of NW corner of section 33, T. 18 N, R. 4 W, on west line of section 33, 1341 m southeast of point "1009 ft" on Logan Ridge, Lodoga Quadrangle (15 minute, 1943), Colusa County, northern California. Upper part of Antelope Shale, stratigraphic unit 7c of Brown and Rich (1961) and approximately 12 m below base of Venado Sandstone Member of Cortina formation (informal). Cenomanian. Collectors: R. D. Brown, Jr. & E. I. Rich, 1958.

USGS M-177. Concretionary silty sandstone bed (approximately 1 m thick), 366 m N, 61 m E of SW corner of section 33, T. 18 N, R. 4 W, 1920 m S-SE of point "1009 ft" on Logan Ridge, Lodoga Quadrangle (15 minute, 1943), Colusa County, northern California. Upper part of Antelope Shale, stratigraphic unit 7c of Brown & Rich (1961) and approximately 23 to 30 m below base of Venado Sandstone Member of Cortina formation (informal). Cenomanian. Collectors: R. D. Brown, Jr., & E. I. Rich, 1958.

USGS M-178. Calcareous pebble conglomerate with abundant broken shell material, 146 m E, 594 m S of NW corner of section 32, T. 19 N, R. 4 W, Lodoga Quadrangle (15 minute, 1943), Colusa County, northern California. Upper part of Antelope Shale, approximately 905 m below base of Venado Sandstone Member of Cortina formation (informal). Cenomanian. Collectors: R. D. Brown, Jr., & E. I. Rich, 1958.

USGS M-8830. Conglomerate at W end of Fish Rock Beach, Anchor Bay, SW/4 of section 18, T. 11 N, R. 15 W, Gualala Quadrangle (7.5 minute, 1969), Mendocino County, northern California. Gualala Formation, Anchor Bay Member. Late Campanian to early Maastrichtian. Collector: W. P. Elder, 1992.